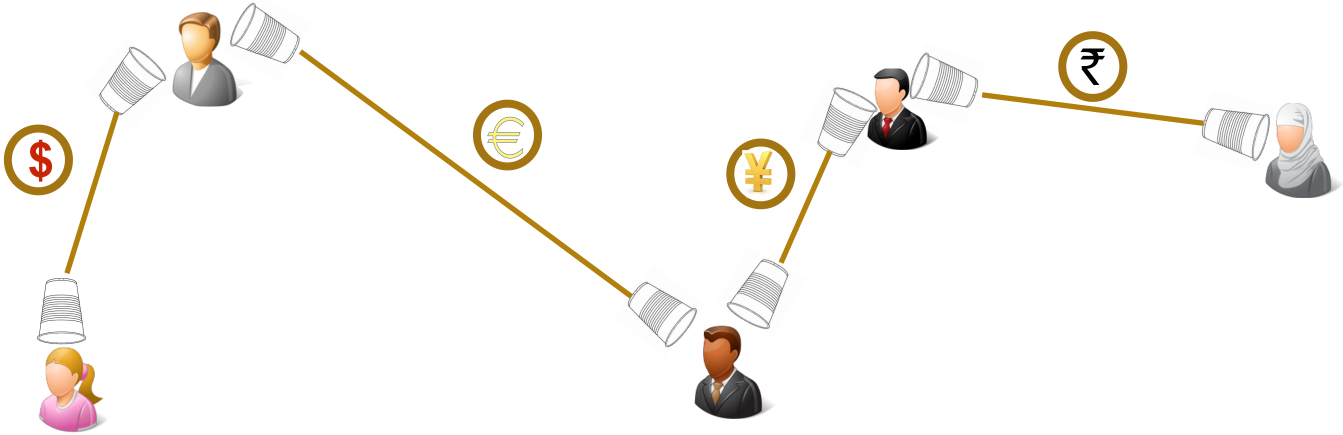
# SilentWhispers: Enforcing Security and Privacy in Decentralized Credit Networks



Giulio Malavolta
Saarland University

**Pedro Moreno-Sanchez**
Purdue University

Aniket Kate
Purdue University

Matteo Maffei
TU Vienna

***NDSS 2017***

# Yet Another Talk about Cryptocurrencies?

- TumbleBit and CoinShuffle++ are excellent ideas to provide privacy in Bitcoin

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  - High power consumption for proof-of-work

# Yet Another Talk about Cryptocurrencies?

- TumbleBit and CoinShuffle++ are excellent ideas to provide privacy in Bitcoin

- Bitcoin (as other permissionless cryptocurrencies) relies on a blockchain:
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  - High power consumption for proof-of-work

Is it possible to have a decentralized payment system without a blockchain?

# Credit (or IOU Settlement) Networks: Basics

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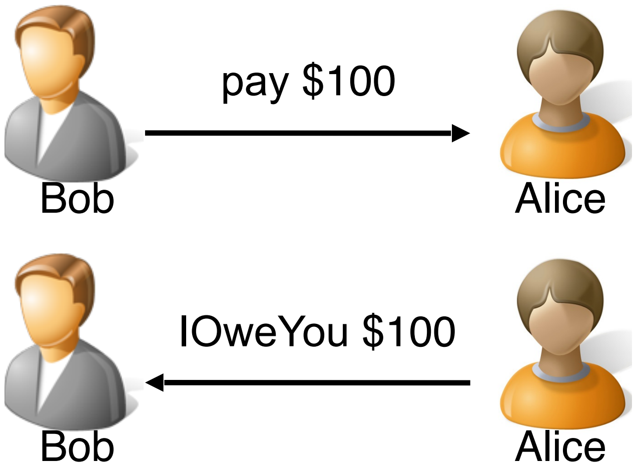
## Transactions in the real world



Bob

pay $100

Alice

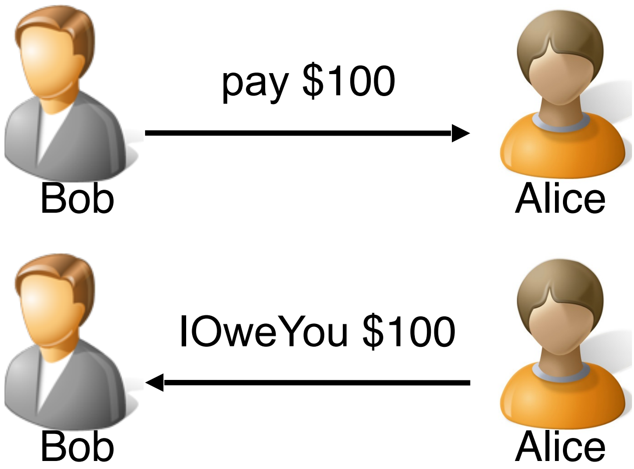
Bob

IOweYou $100

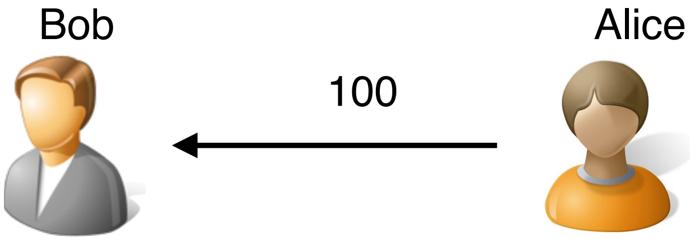
Alice

# Credit (or IOU Settlement) Networks: Basics

## Transactions in the real world



## A credit network representation



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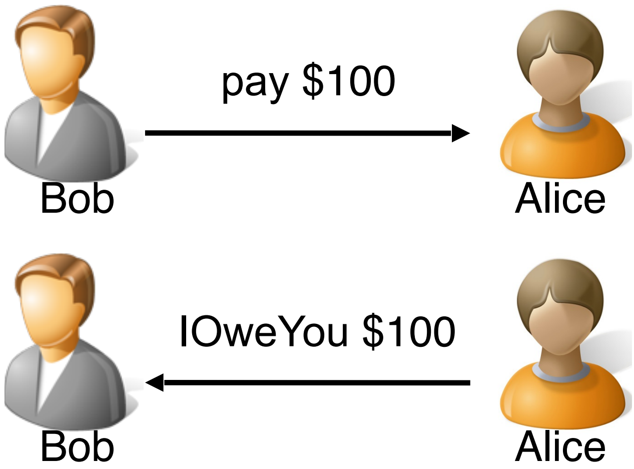


pay $100

Bob

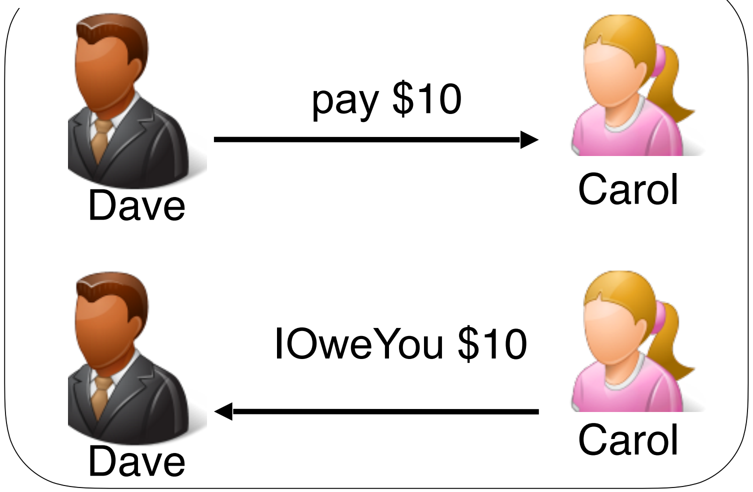
Alice

IOweYou $100

Bob

Alice

During a hike with Alice & Bob



pay $10

Dave

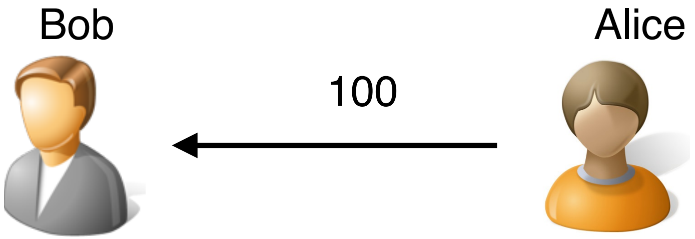
Carol

IOweYou $10

Dave

Carol

## A credit network representation



Bob

100

Alice

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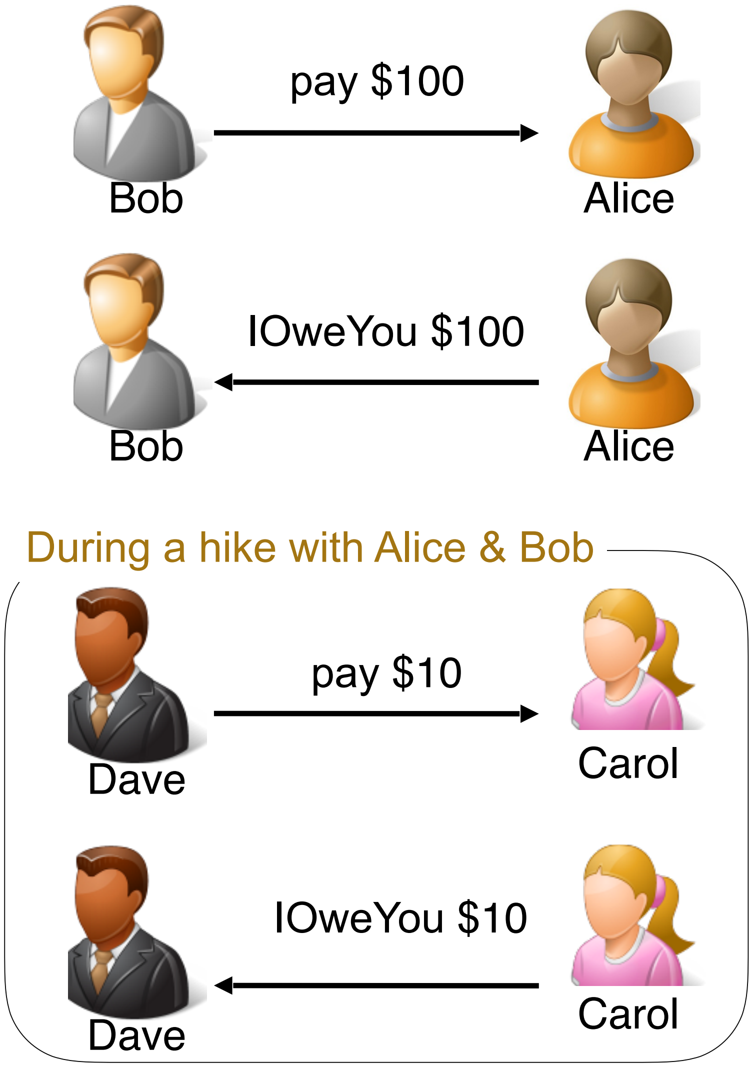

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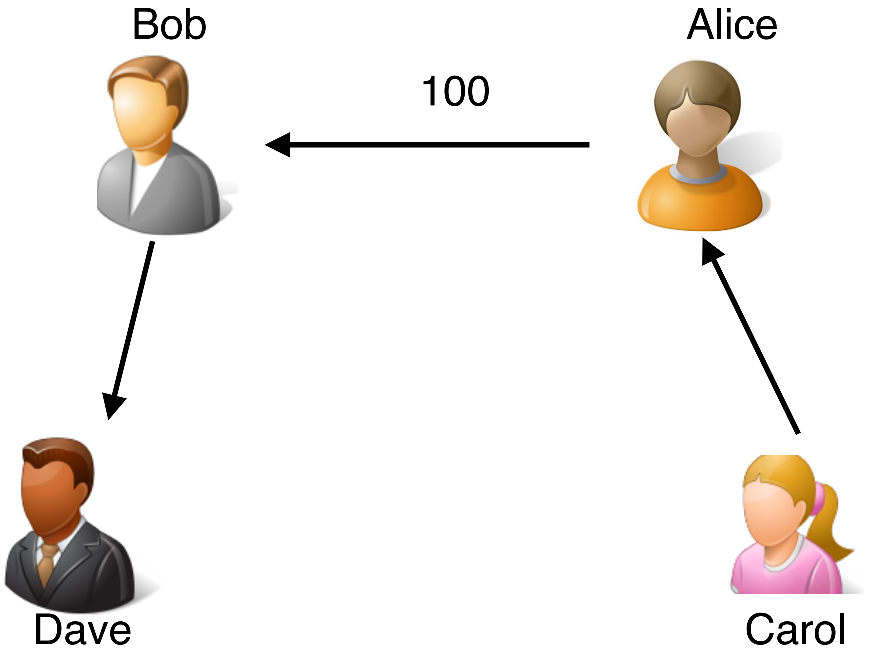

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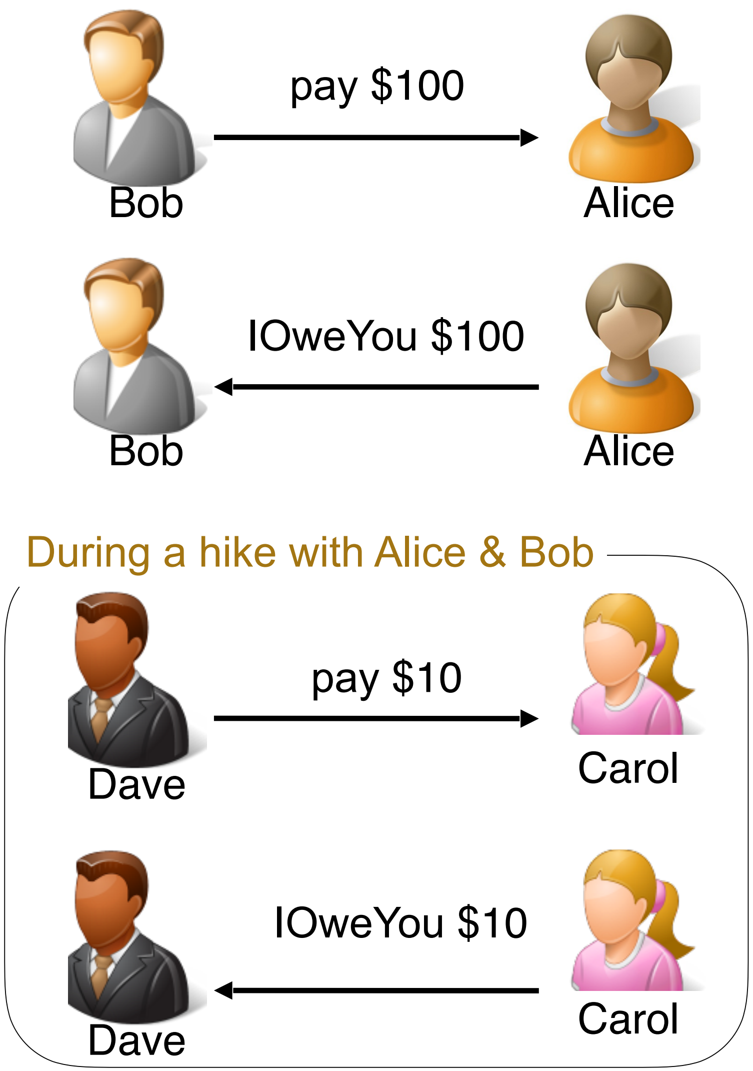


Bob pay $100 Alice

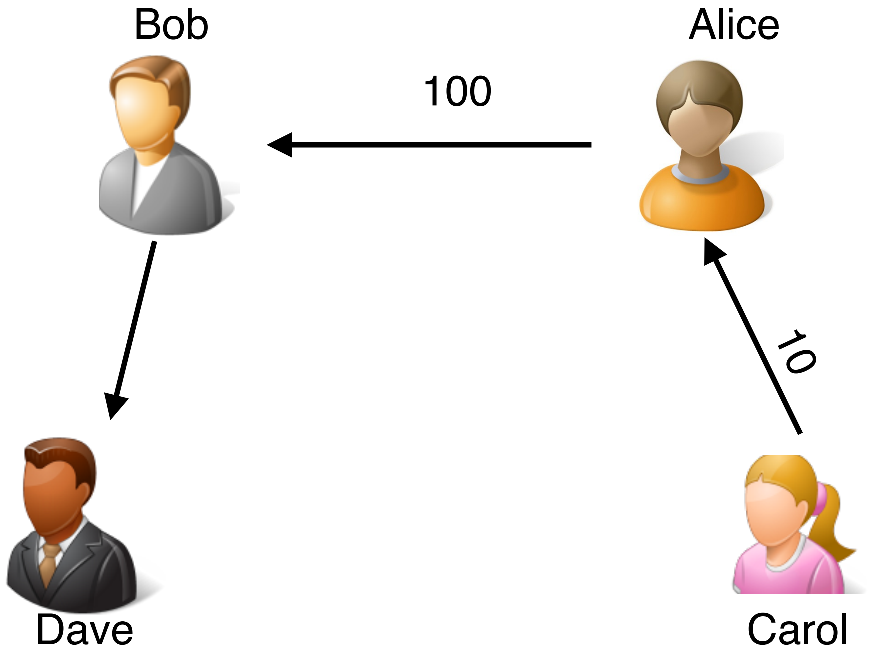
Bob IOweYou $100 Alice

During a hike with Alice & Bob

Dave pay $10 Carol

Dave IOweYou $10 Carol

## A credit network representation



Bob

Alice

100

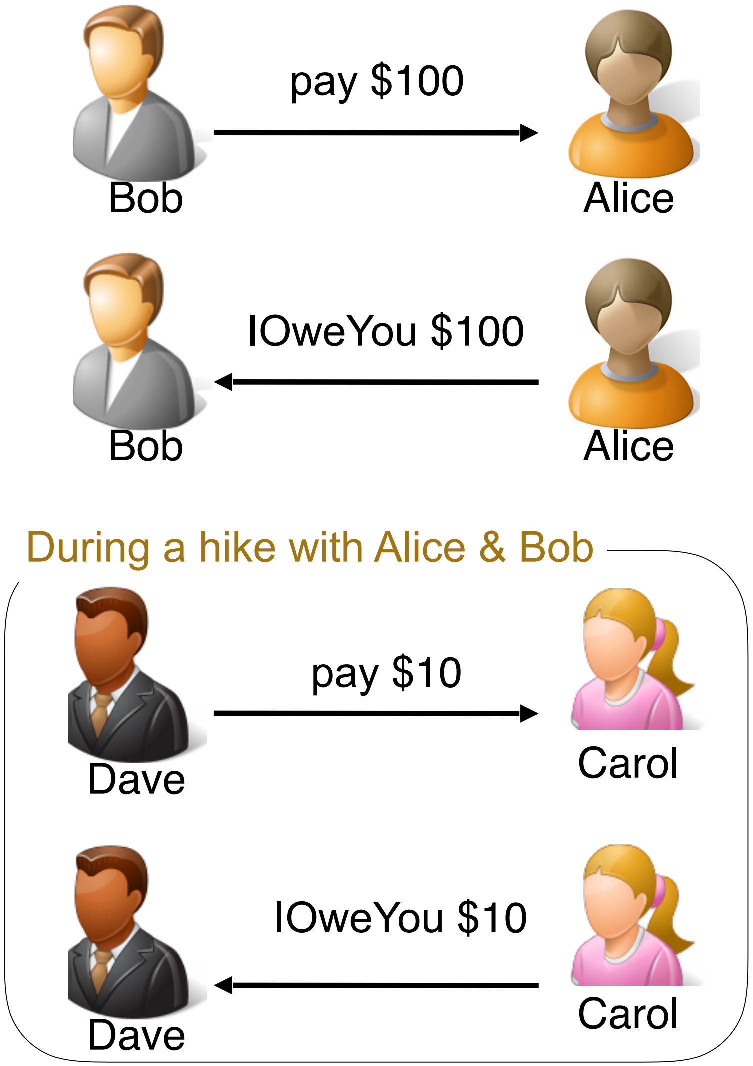
10

Dave

Carol

# Credit (or IOU Settlement) Networks: Basics

## Transactions in the real world



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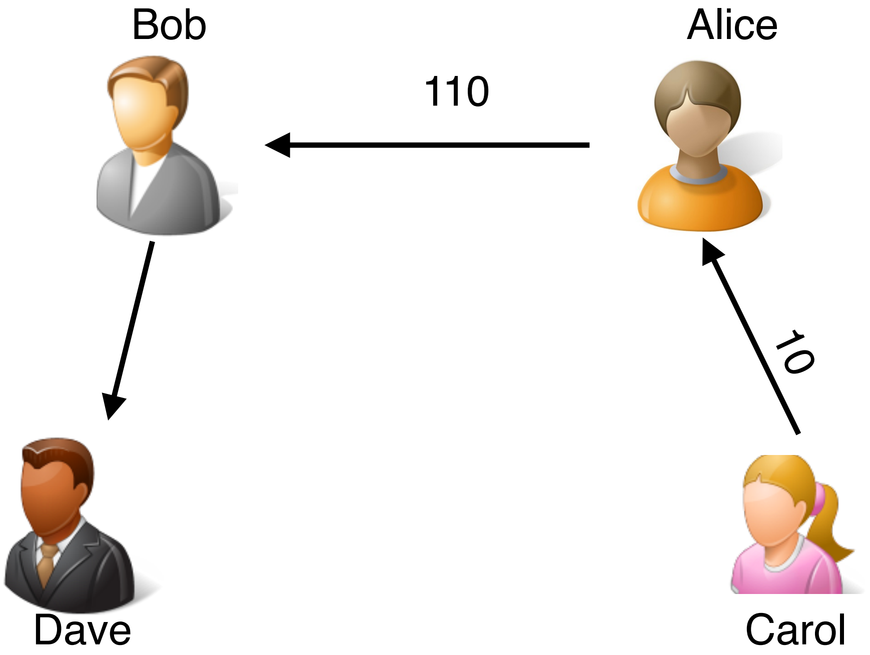

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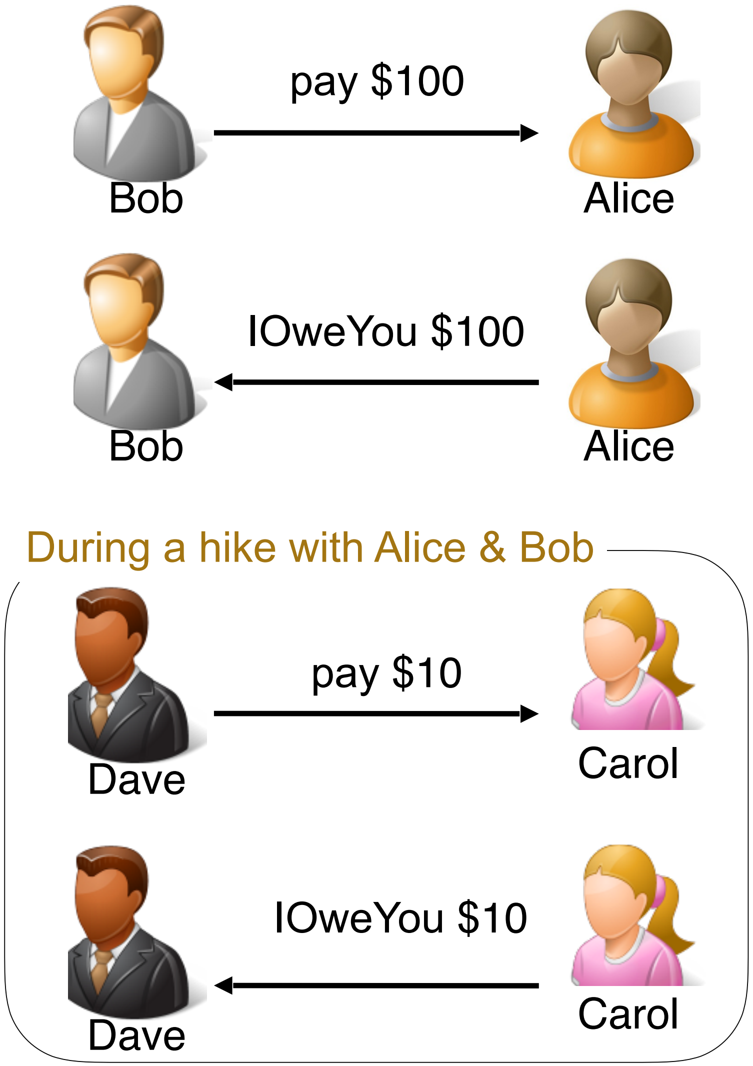

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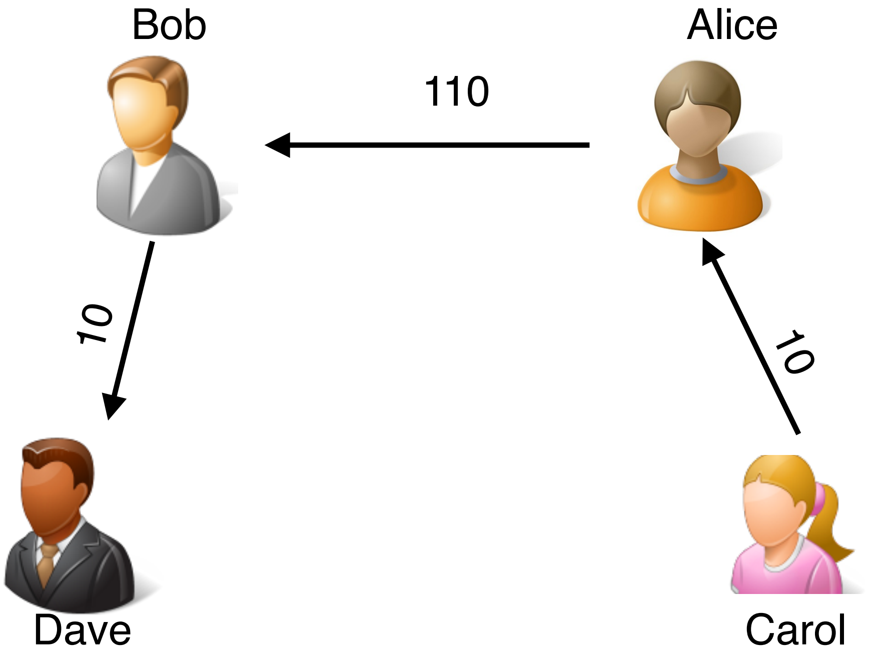


# Credit Network Examples

- Academic proposals:
  - Ostra: preventing e-mail spam [NSDI'08]

  - Bazaar: strengthening e-commerce [NSDI'11]
  - SumUp: Sybil-resilient content voting [NSDI'09]

- Industry deployments:
  - Ripple: A real-life online payment network
  - Stellar: Another real-life online payment network

# Credit Network Examples

- Academic proposals:
  - Ostra: preventing e-mail spam [NSDI'08]

Sent Mail

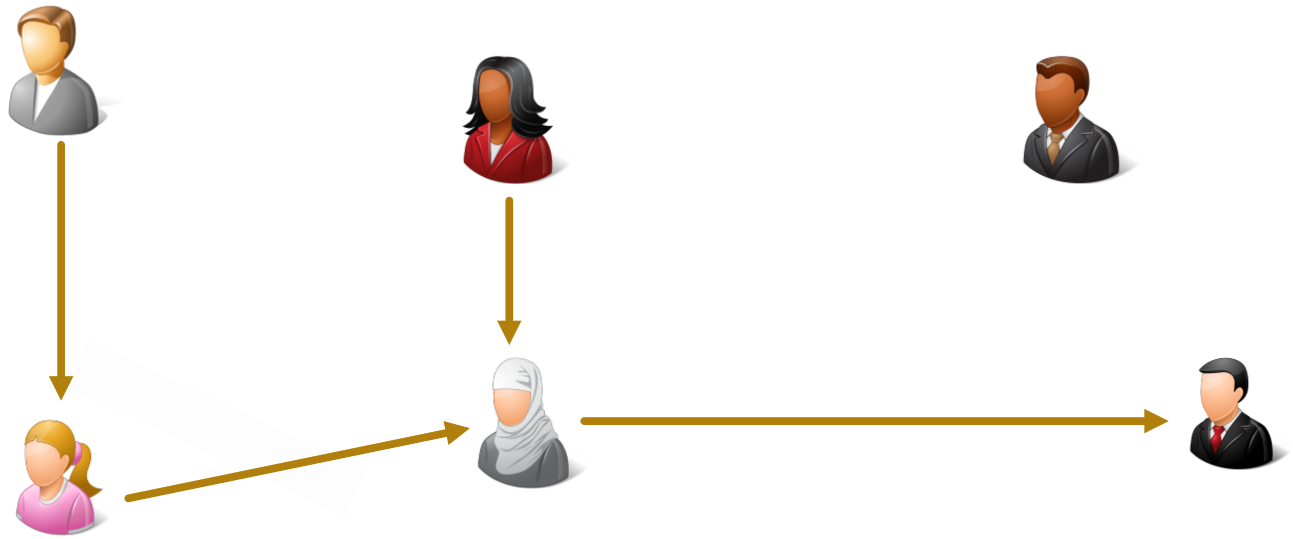
Spam (372)

Trash

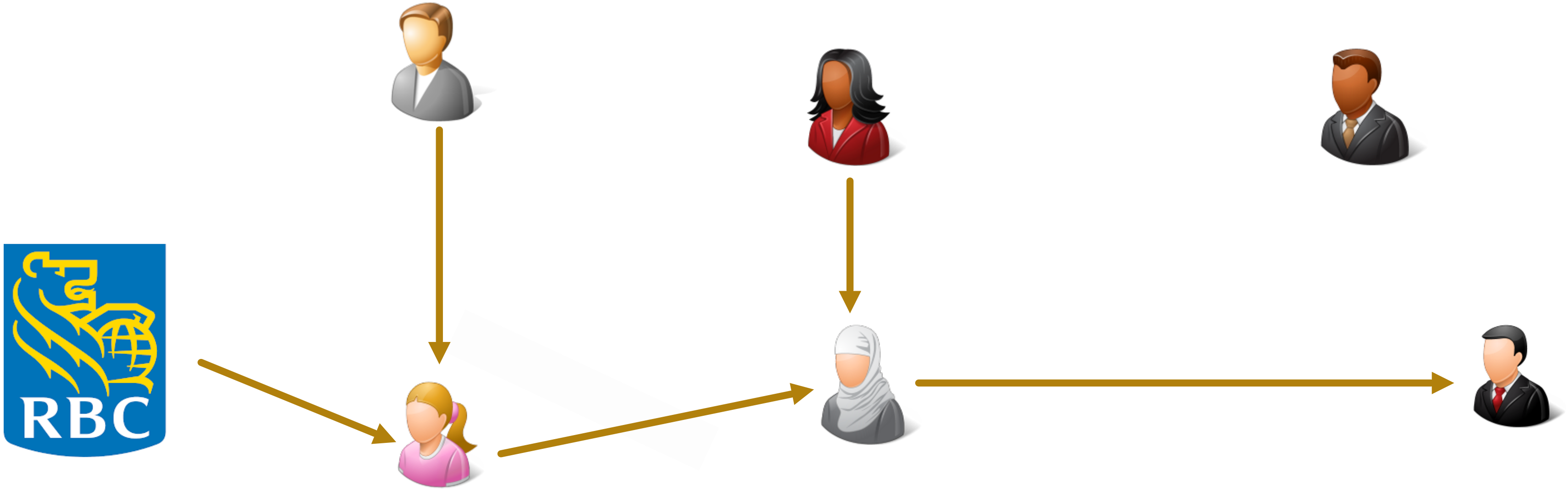
  - Bazaar: strengthening e-commerce [NSDI'11]
  - SumUp: Sybil-resilient content voting [NSDI'09]

- Industry deployments:
  - Ripple: A real-life online payment network
  - Stellar: Another real-life online payment network

# Ripple Credit Network



# Ripple Credit Network



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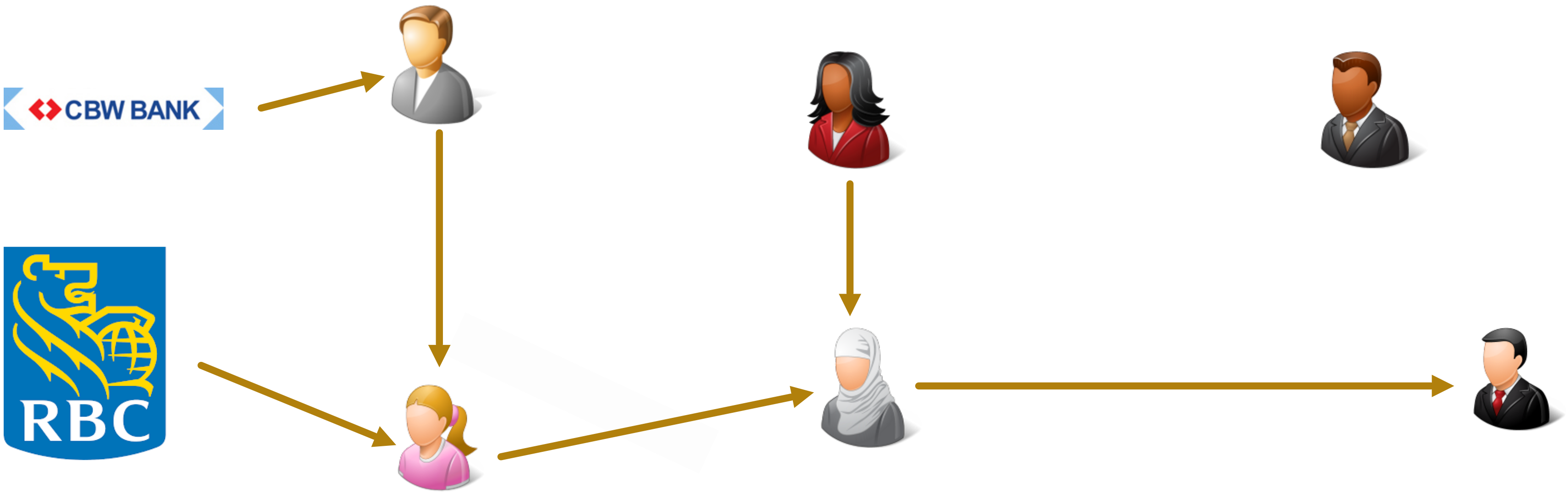

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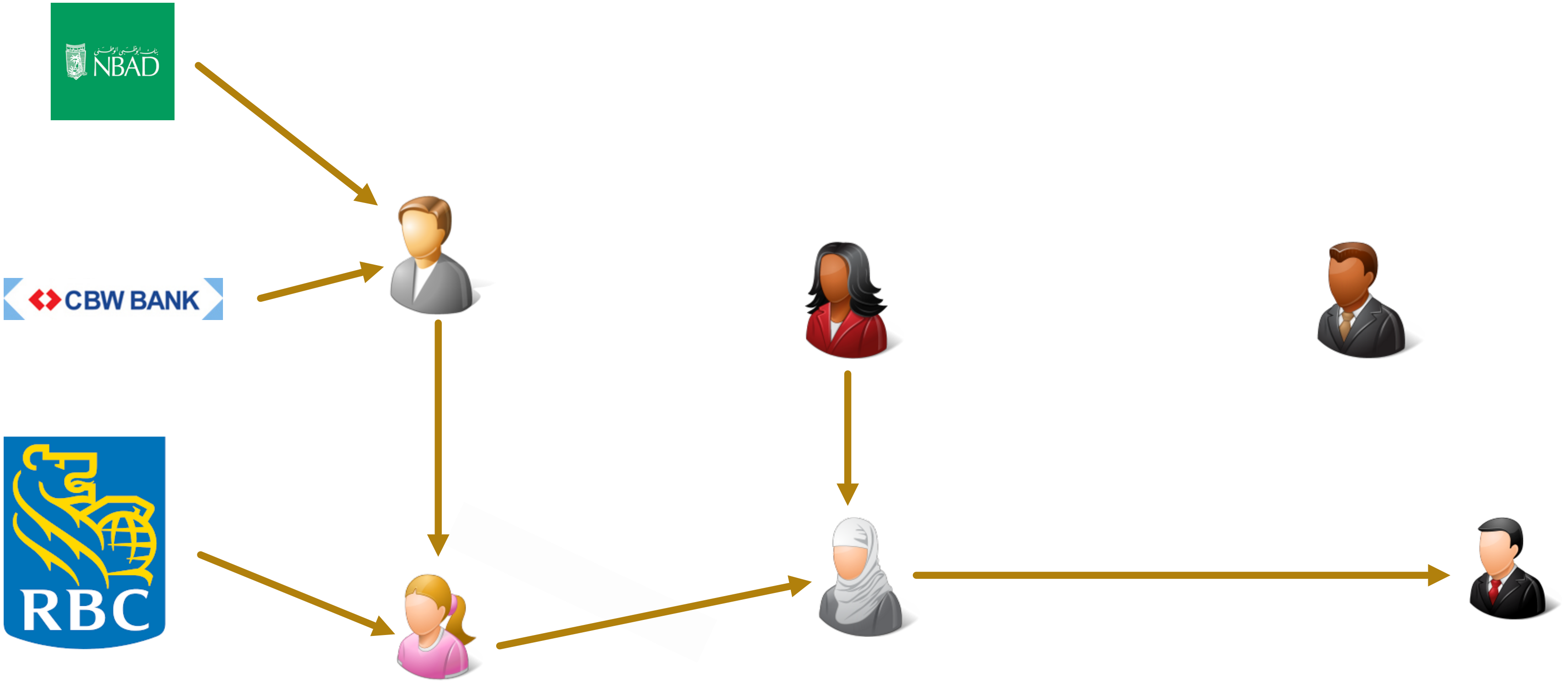

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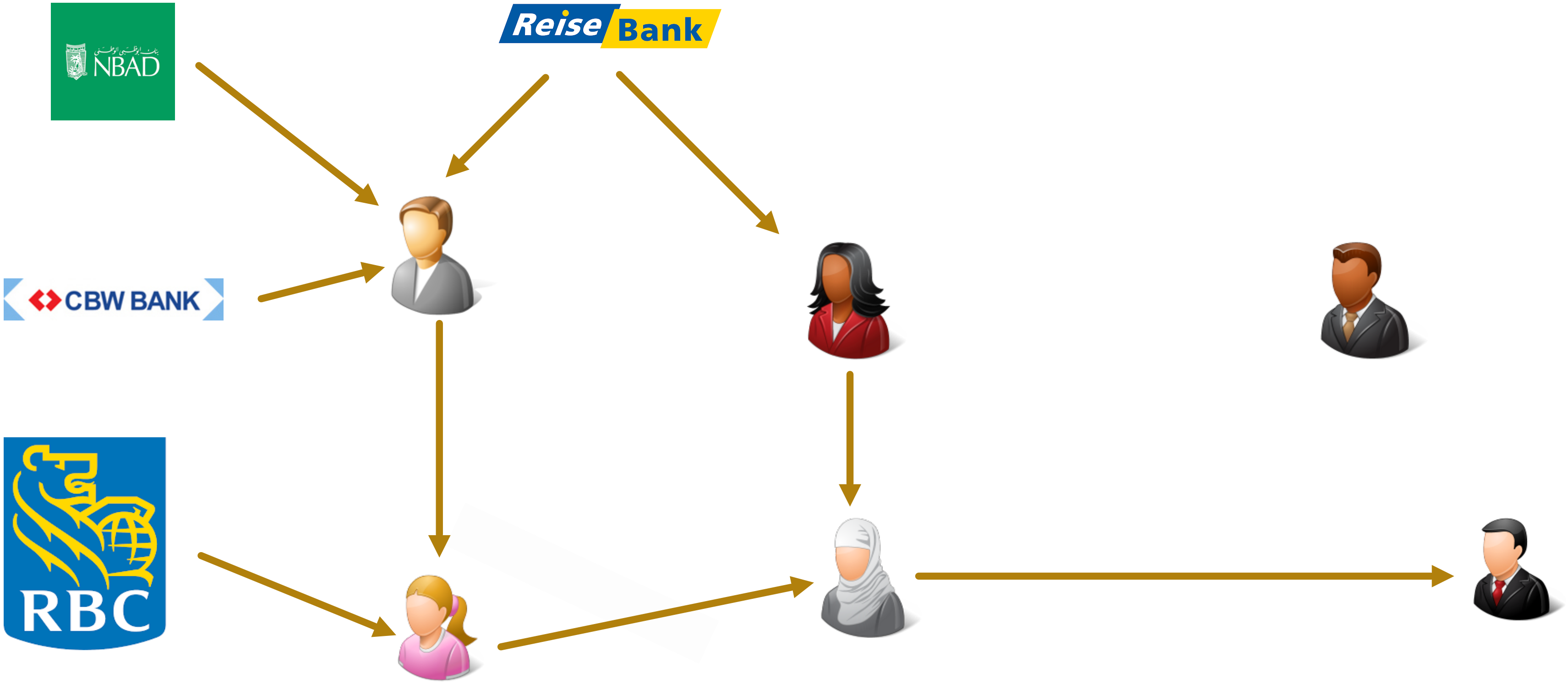

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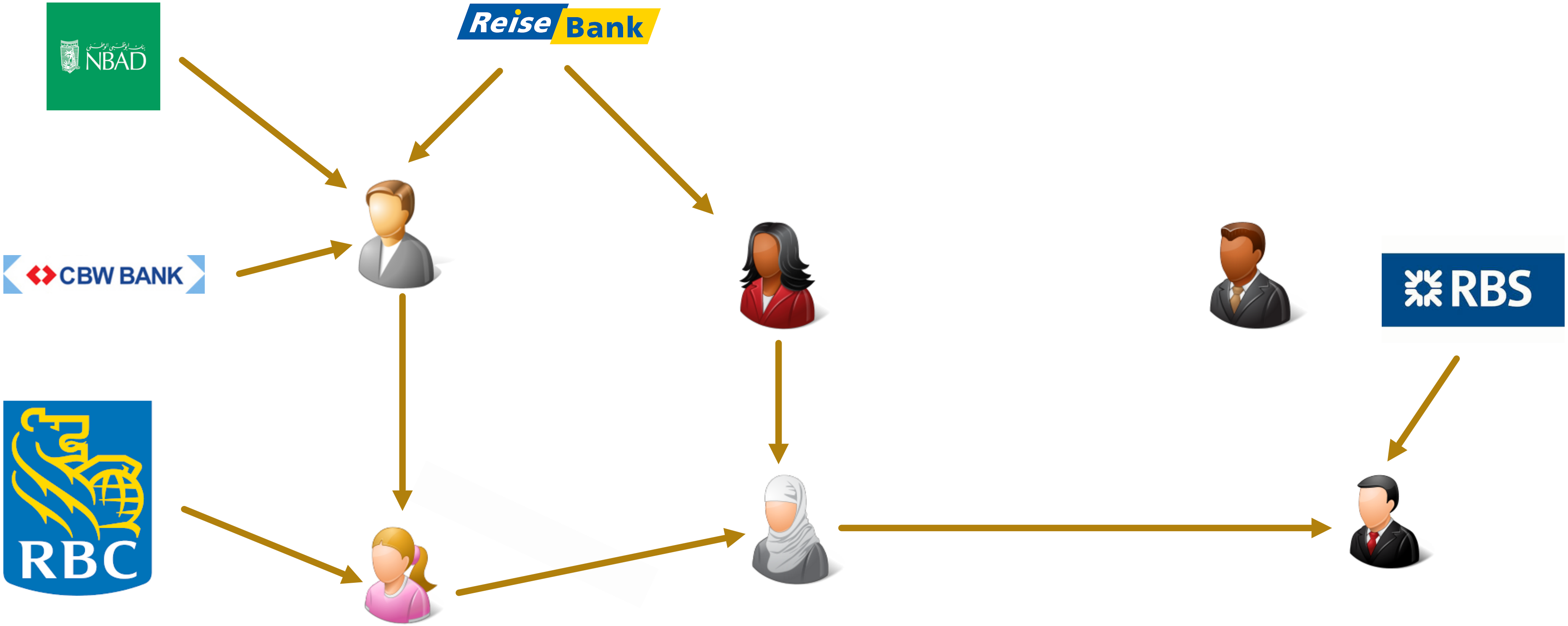

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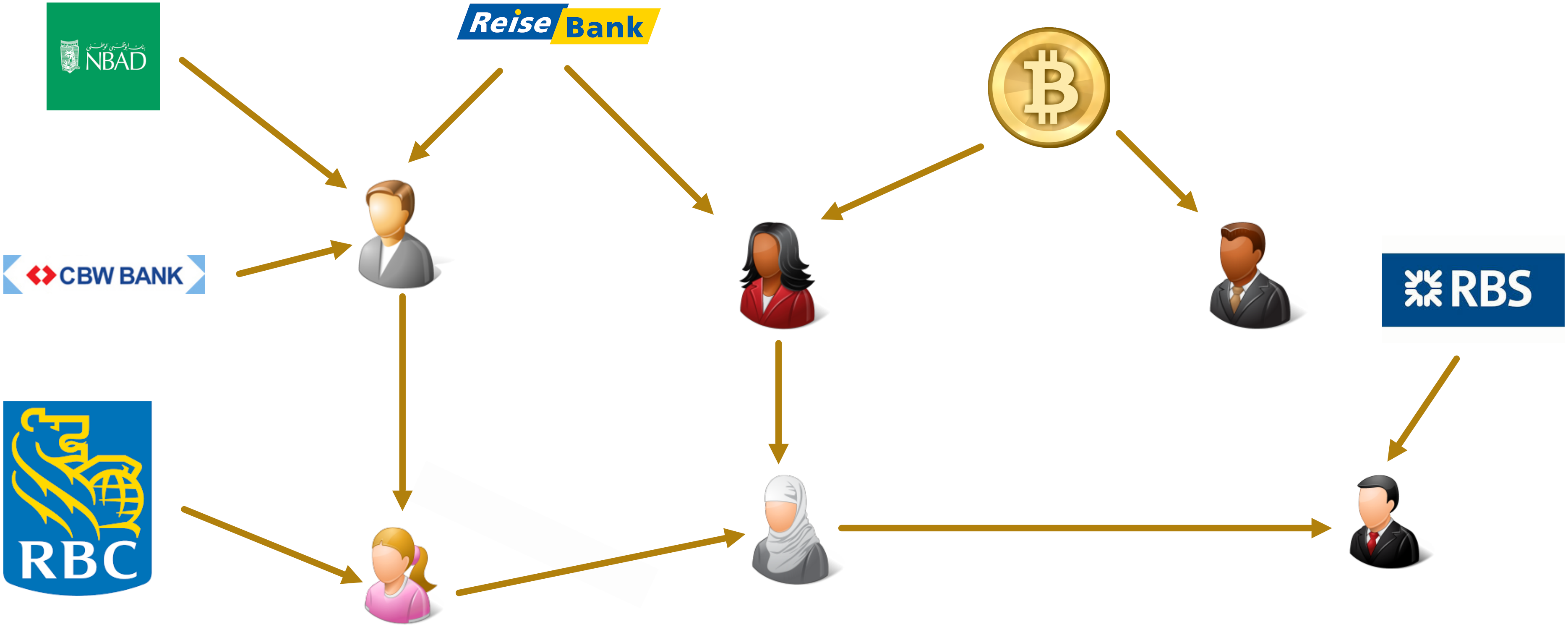

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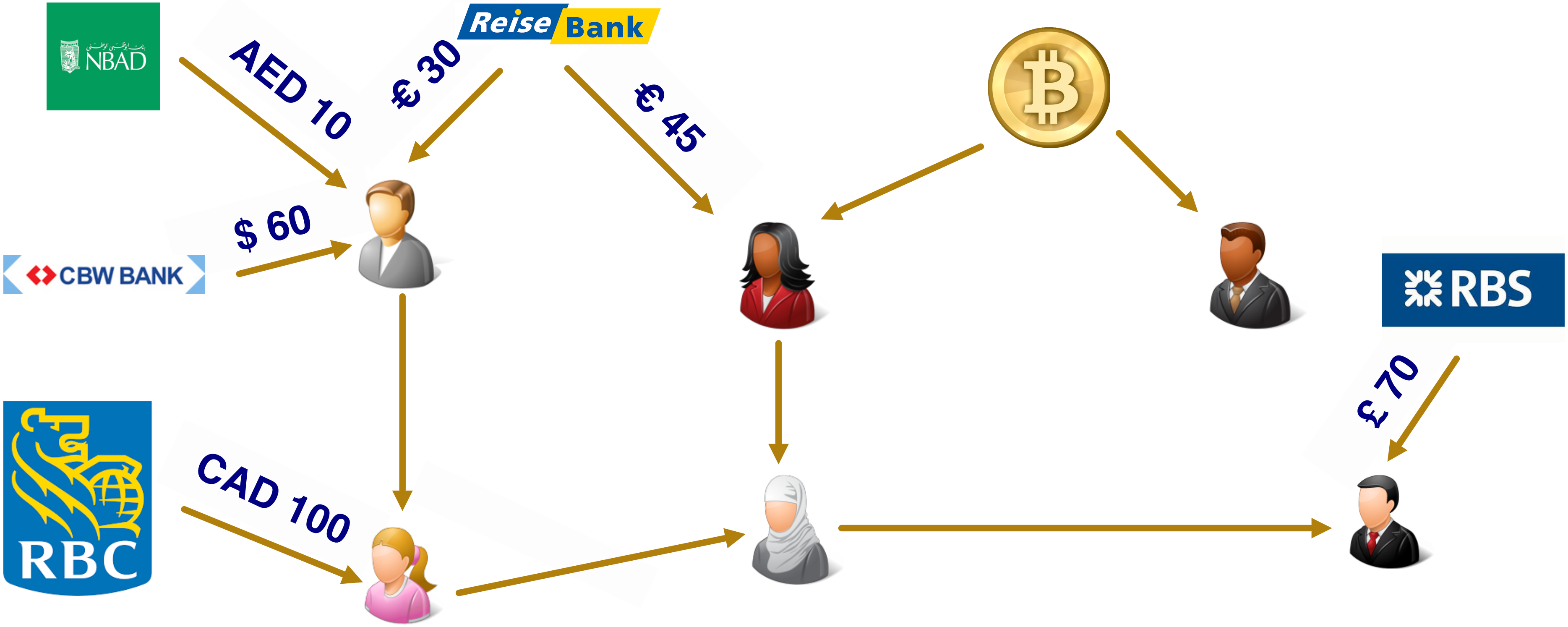

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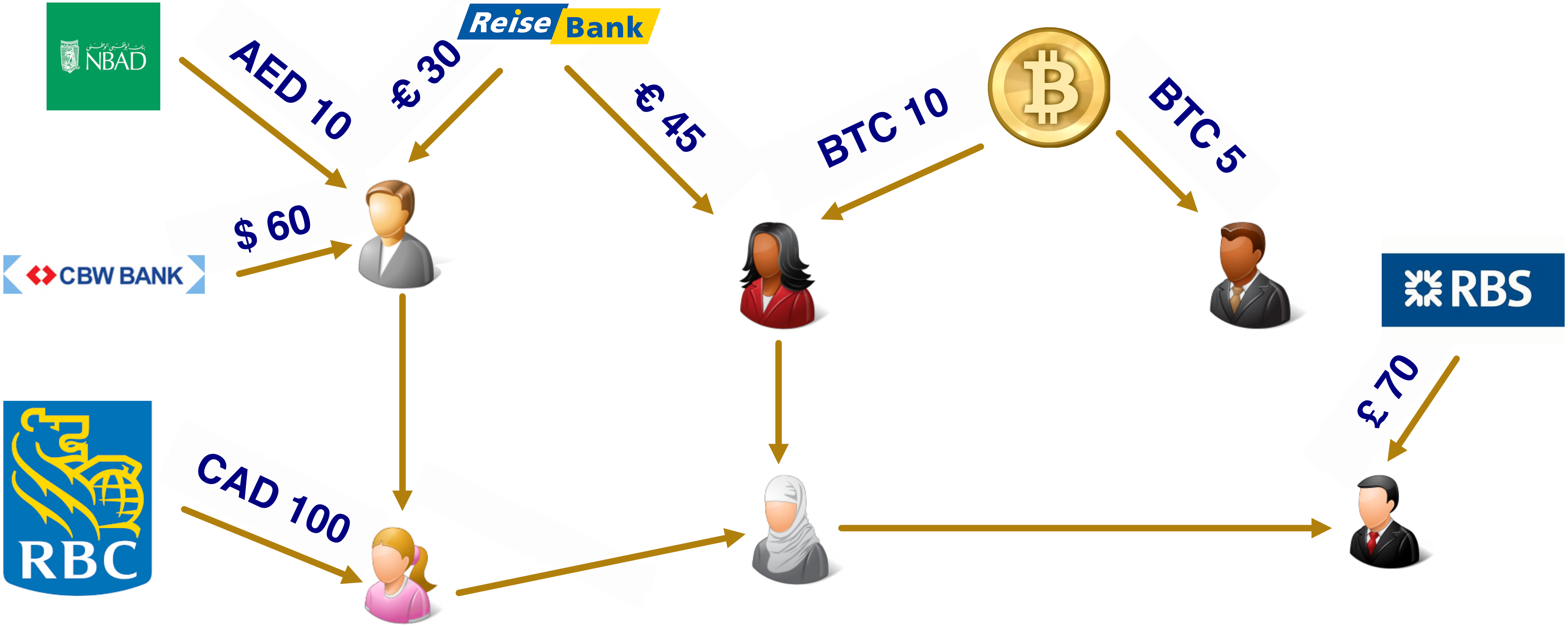

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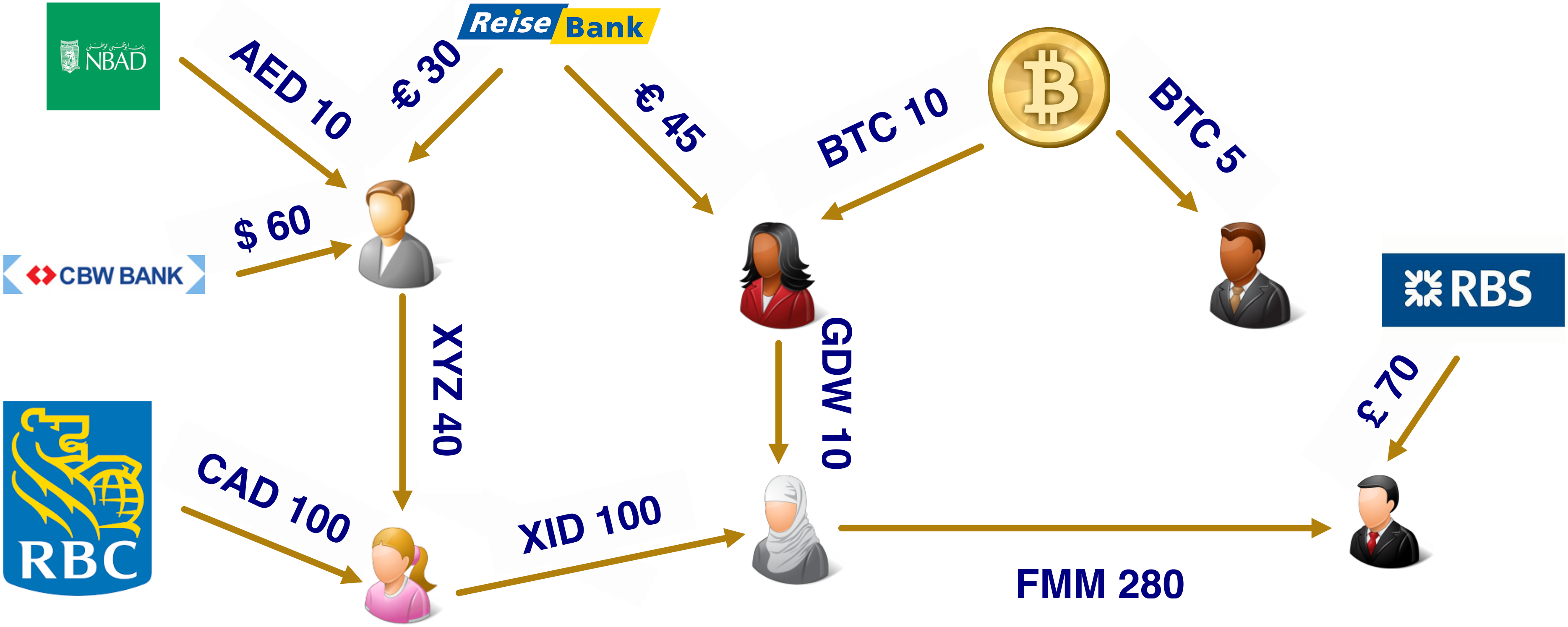

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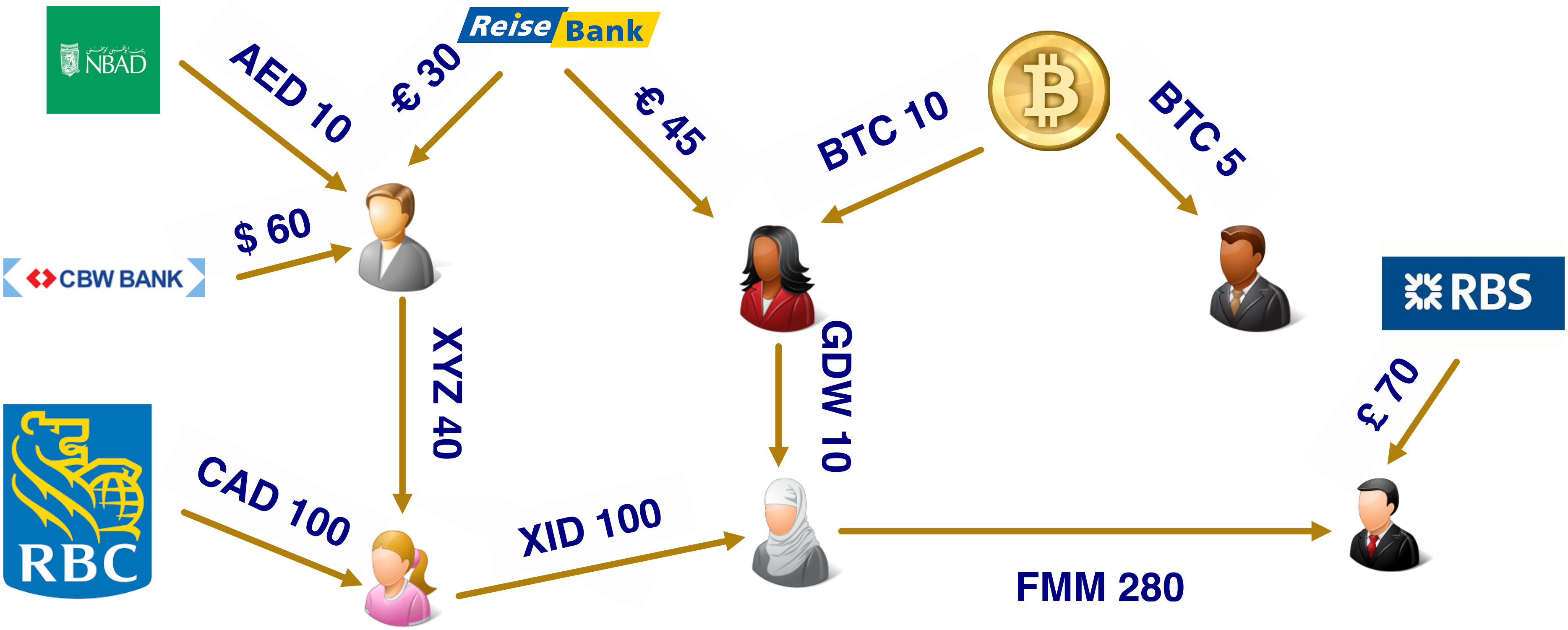
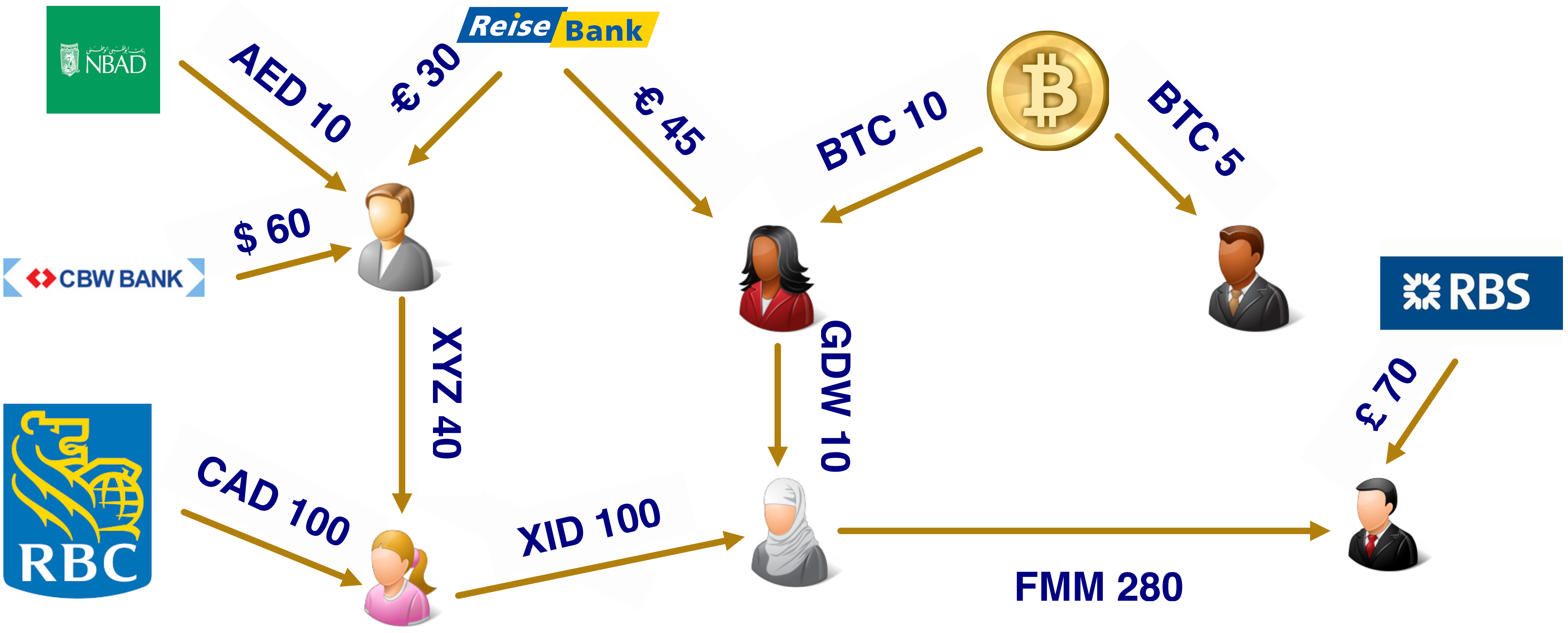


Tx time

Worldwide,
cross-currency tx

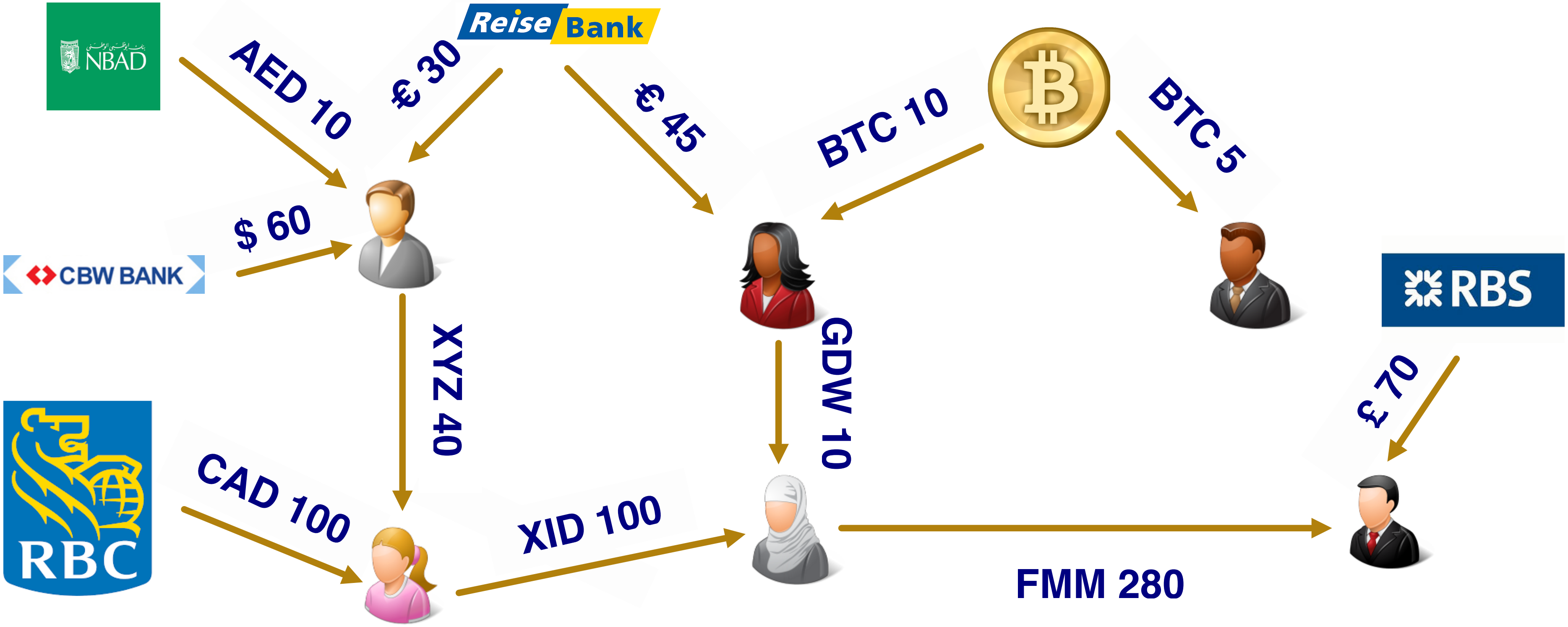
Integrity

# Ripple Credit Network



| | Tx time | Worldwide, cross-currency tx | Integrity |
|---|---|---|---|
| BANK | ~ 1 day | | |
| ripple | ~ 5 seconds | | |

# Ripple Credit Network



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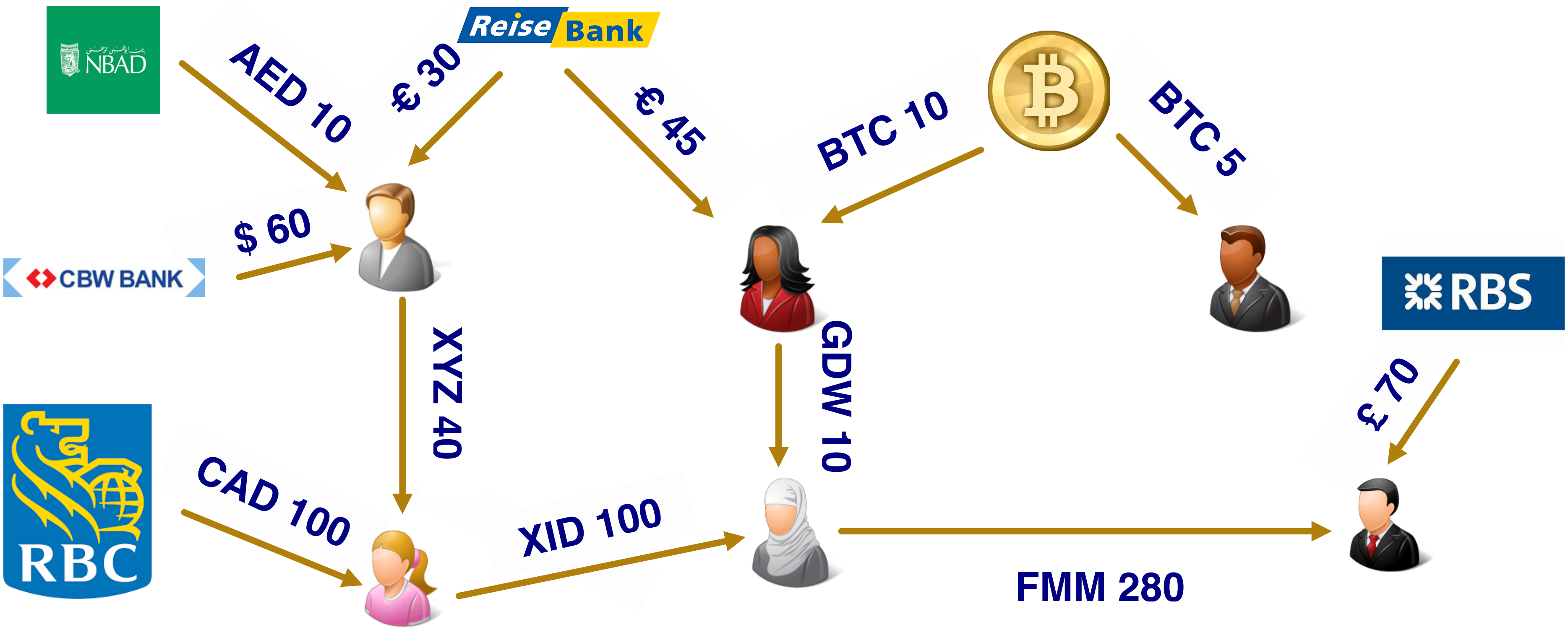

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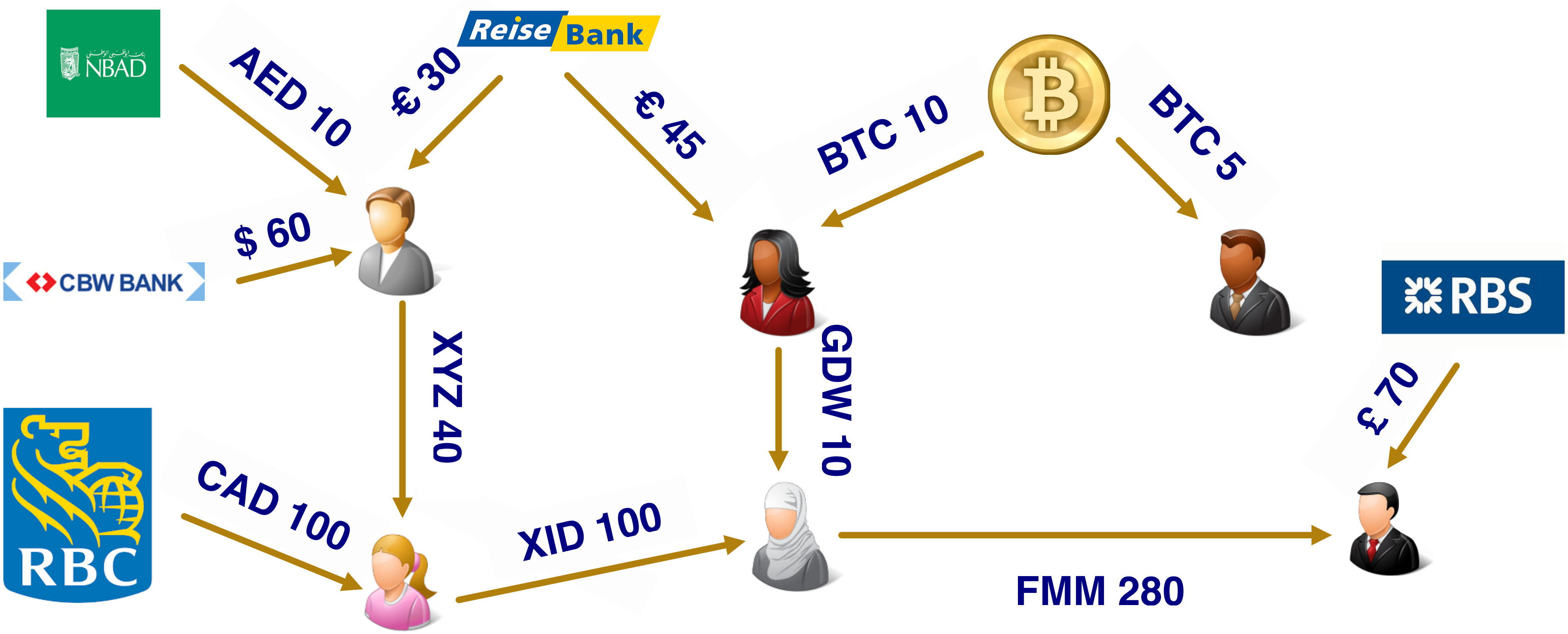

| | Tx time | Worldwide, cross-curr | Integrity |
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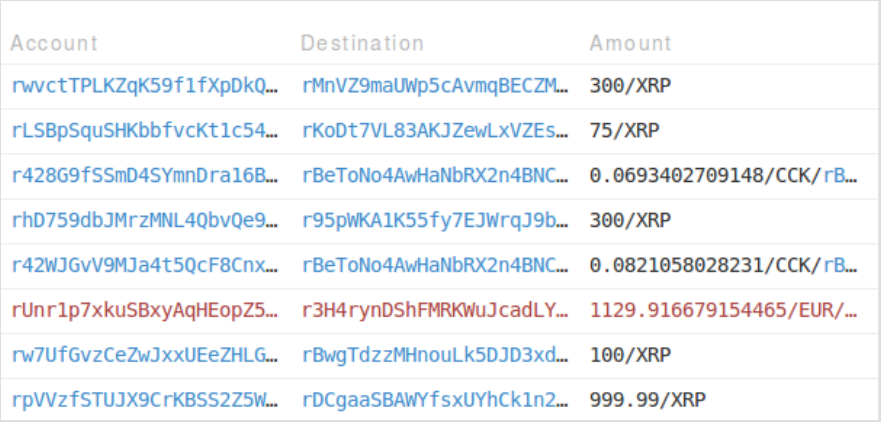
Ripple can significantly improve cross-currency remittance and settlements

# Public Verifiability & Privacy Problem

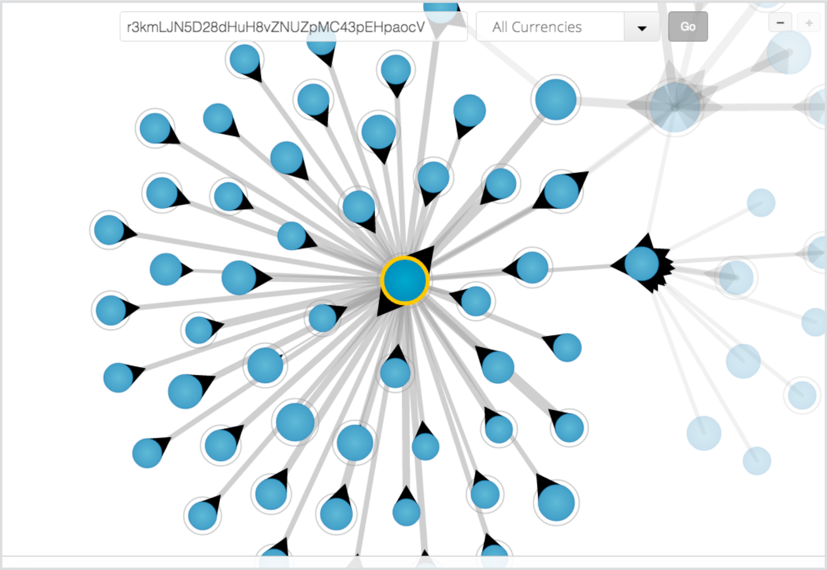
## The Ripple Ledger

### Transaction Details



| Account | Destination | Amount |
|---|---|---|
| rwvctTPLKZqK59f1fXpDkQ… | rMnVZ9maUWp5cAvmqBECZM… | 300/XRP |
| rLSBpSquSHKbbfvcKt1c54… | rKoDt7VL83AKJZewLxVZEs… | 75/XRP |
| r428G9fSSmD4SYmnDra16B… | rBeToNo4AwHaNbRX2n4BNC… | 0.0693402709148/CCK/rB… |
| rhD759dbJMrzMNL4QbvQe9… | r95pWKA1K55fy7EJWrqJ9b… | 300/XRP |
| r42WJGvV9MJa4t5QcF8Cnx… | rBeToNo4AwHaNbRX2n4BNC… | 0.0821058028231/CCK/rB… |
| rUnr1p7xkuSBxyAqHEopZ5… | r3H4rynDShFMRKWuJcadLY… | 1129.916679154465/EUR/… |
| rw7UfGvzCeZwJxxUEeZHLG… | rBwgTdzzMHnouLk5DJD3xd… | 100/XRP |
| rpVVzfSTUJX9CrKBSS2Z5W… | rDCgaaSBAWYfsxUYhCk1n2… | 999.99/XRP |

### Credit Graph



r3kmLJN5D28dHuH8vZNUZpMC43pEHpaocV

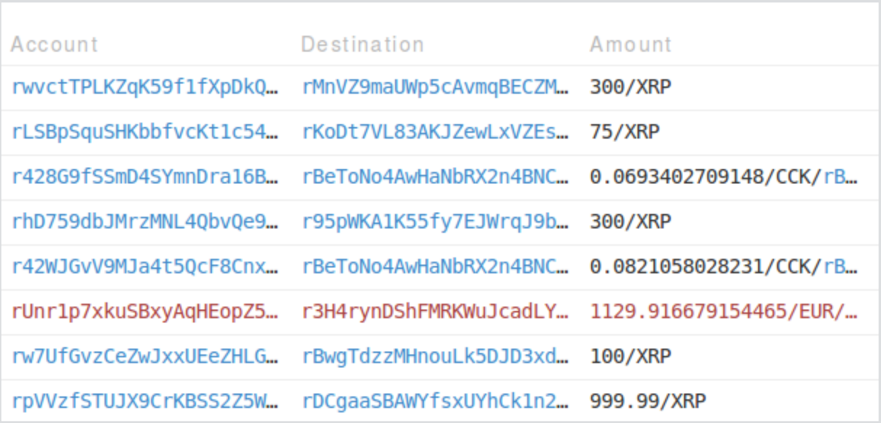
All Currencies

# Public Verifiability & Privacy Problem

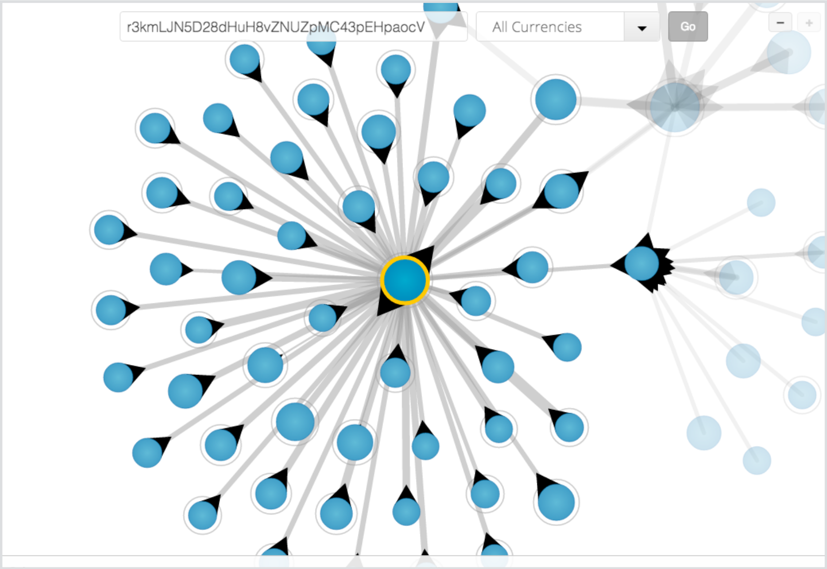
## The Ripple Ledger

### Credit Graph

### Transaction Details



| Account | Destination | Amount |
|---|---|---|
| rwvctTPLKZqK59f1fXpDkQ… | rMnVZ9maUWp5cAvmqBECZM… | 300/XRP |
| rLSBpSquSHKbbfvcKt1c54… | rKoDt7VL83AKJZewLxVZEs… | 75/XRP |
| r428G9fSSmD4SYmnDra16B… | rBeToNo4AwHaNbRX2n4BNC… | 0.0693402709148/CCK/rB… |
| rhD759dbJMrzMNL4QbvQe9… | r95pWKA1K55fy7EJWrqJ9b… | 300/XRP |
| r42WJGvV9MJa4t5QcF8Cnx… | rBeToNo4AwHaNbRX2n4BNC… | 0.0821058028231/CCK/rB… |
| rUnr1p7xkuSBxyAqHEopZ5… | r3H4rynDShFMRKWuJcadLY… | 1129.916679154465/EUR/… |
| rw7UfGvzCeZwJxxUEeZHLG… | rBwgTdzzMHnouLk5DJD3xd… | 100/XRP |
| rpVVzfSTUJX9CrKBSS2Z5W… | rDCgaaSBAWYfsxUYhCk1n2… | 999.99/XRP |



**Listening to Whispers of Ripple: Linking Wallets and Deanonymizing Transactions in the Ripple Network**

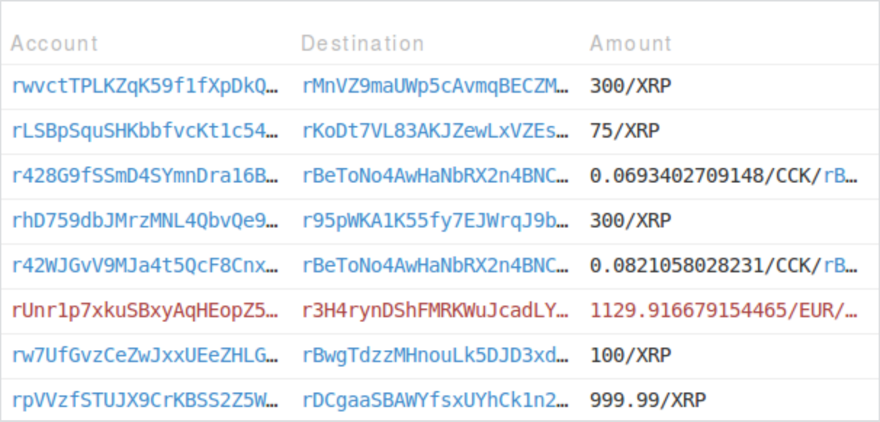
Pedro Moreno-Sanchez, Muhammad Bilal Zafar, Aniket Kate.

PETS '16

# Public Verifiability & Privacy Problem

## The Ripple Ledger

### Transaction Details



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|---|---|---|
| rwvctTPLKZqK59f1fXpDkQ… | rMnVZ9maUWp5cAvmqBECZM… | 300/XRP |
| rLSBpSquSHKbbfvcKt1c54… | rKoDt7VL83AKJZewLxVZEs… | 75/XRP |
| r428G9fSSmD4SYmnDra16B… | rBeToNo4AwHaNbRX2n4BNC… | 0.0693402709148/CCK/rB… |
| rhD759dbJMrzMNL4QbvQe9… | r95pWKA1K55fy7EJWrqJ9b… | 300/XRP |
| r42WJGvV9MJa4t5QcF8Cnx… | rBeToNo4AwHaNbRX2n4BNC… | 0.0821058028231/CCK/rB… |
| rUnr1p7xkuSBxyAqHEopZ5… | r3H4rynDShFMRKWuJcadLY… | 1129.916679154465/EUR/… |
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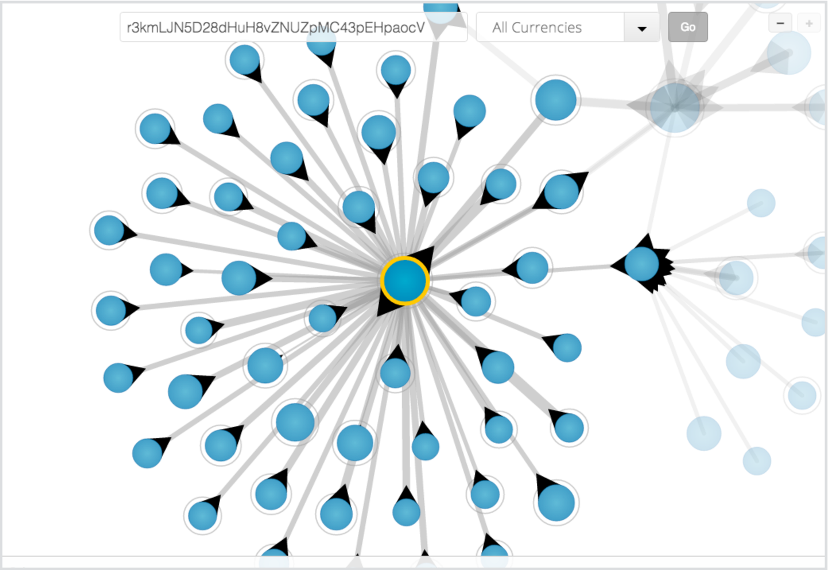

r3kmLJN5D28dHuH8vZNUZpMC43pEHpaocV

All Currencies

**Listening to Whispers of Ripple: Linking Wallets and Deanonymizing Transactions in the Ripple Network**

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PETS ‘16

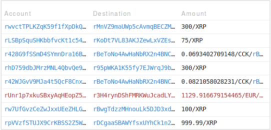
Current credit networks employ a global ledger

# Our Contributions

- We question the need for a global ledger and global consensus

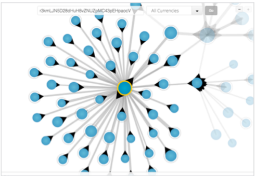
The Ripple Ledger

Transaction Details



| Account | Destination | Amount |
|---|---|---|
| rwvctTPLKZqK59f1fXpDkQ… | rMnVZ9maUWp5cAvmqBECZM… | 300/XRP |
| rLSBpSquSHKbbfvcKt1c54… | rKoDt7VL83AKJZewLxVZEs… | 75/XRP |
| r428G9fSSmD4SYmnDra16B… | rBeToNo4AwHaNbRX2n4BNC… | 0.0693402709148/CCK/rB… |
| rhD759dbJMrzMNL4QbvQe9… | r95pWKA1K55fy7EJWrqJ9b… | 300/XRP |
| r42WJGvV9MJa4t5QcF8Cnx… | rBeToNo4AwHaNbRX2n4BNC… | 0.0821058028231/CCK/rB… |
| rUnr1p7xkuSBxyAqHEopZ5… | r3H4rynDShFMRKWuJcadLY… | 1129.916679154465/EUR/… |
| rw7UfGvzCeZwJxxUEeZHLG… | rBwgTdzzMHnouLk5DJD3xd… | 100/XRP |
| rpVVzfSTUJX9CrKBSS2Z5W… | rDCgaaSBAWYfsxUYhCk1n2… | 999.99/XRP |

Credit Graph

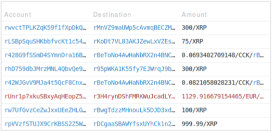


# Our Contributions

- We question the need for a global ledger and global consensus

The Ripple Ledger

Transaction Details



| Account | Destination | Amount |
|---|---|---|
| rwvctTPLKZqK59f1fXpDkQ… | rMnVZ9maUWp5cAvmqBECZM… | 300/XRP |
| rLSBpSquSHKbbfvcKt1c54… | rKoDt7VL83AKJZewLxVZEs… | 75/XRP |
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| rhD759dbJMrzMNL4QbvQe9… | r95pWKA1K55fy7EJWrqJ9b… | 300/XRP |
| r42WJGvV9MJa4t5QcF8Cnx… | rBeToNo4AwHaNbRX2n4BNC… | 0.0821058028231/CCK/rB… |
| rUnr1p7xkuSBxyAqHEopZ5… | r3H4rynDShFMRKWuJcadLY… | 1129.916679154465/EUR/… |
| rw7UfGvzCeZwJxxUEeZHLG… | rBwgTdzzMHnouLk5DJD3xd… | 100/XRP |
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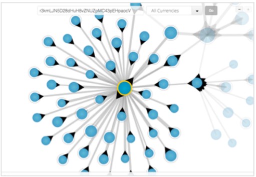
Credit Graph

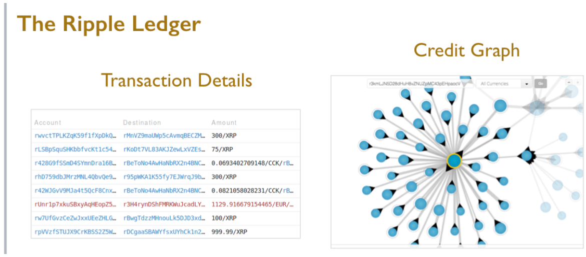


- SilentWhispers: Decentralized credit network with security and privacy guarantees defined in UC framework

**Inspired by our work in NDSS’15**

# Our Contributions

- We question the need for a global ledger and global consensus



The Ripple Ledger

Transaction Details

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| rLSBpSquSHKbbfvcKt1c54… | rKoDt7VL83AKJZewLxVZEs… | 75/XRP |
| r428G9fSSmD4SYmnDra16B… | rBeToNo4AwHaNbRX2n4BNC… | 0.0693402709148/CCK/rB… |
| rhD759dbJMrzMNL4QbvQe9… | r95pWKA1K55fy7EJWrqJ9b… | 300/XRP |
| r42WJGvV9MJa4t5QcF8Cnx… | rBeToNo4AwHaNbRX2n4BNC… | 0.0821058028231/CCK/rB… |
| rUnr1p7xkuSBxyAqHEopZ5… | r3H4rynDShFMRKWuJcadLY… | 1129.916679154465/EUR/… |
| rw7UfGvzCeZwJxxUEeZHLG… | rBwgTdzzMHnouLk5DJD3xd… | 100/XRP |
| rpVVzfSTUJX9CrKBSS2Z5W… | rDCgaaSBAWYfsxUYhCk1n2… | 999.99/XRP |

Credit Graph

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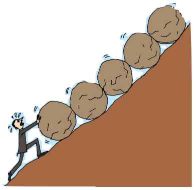

# Our Contributions

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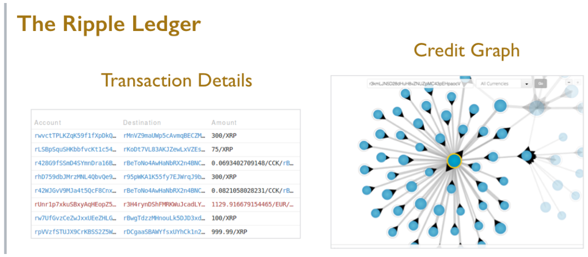

The Ripple Ledger

Transaction Details

| Account | Destination | Amount |
|---|---|---|
| rwvctTPLKZqK59f1fXpDkQ… | rMnVZ9maUWp5cAvmqBECZM… | 300/XRP |
| rLSBpSquSHKbbfvcKt1c54… | rKoDt7VL83AKJZewLxVZEs… | 75/XRP |
| r428G9fSSmD4SYmnDra16B… | rBeToNo4AwHaNbRX2n4BNC… | 0.0693402709148/CCK/rB… |
| rhD759dbJMrzMNL4QbvQe9… | r95pWKA1K55fy7EJWrqJ9b… | 300/XRP |
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| rUnr1p7xkuSBxyAqHEopZ5… | r3H4rynDShFMRKWuJcadLY… | 1129.916679154465/EUR/… |
| rw7UfGvzCeZwJxxUEeZHLG… | rBwgTdzzMHnouLk5DJD3xd… | 100/XRP |
| rpVVzfSTUJX9CrKBSS2Z5W… | rDCgaaSBAWYfsxUYhCk1n2… | 999.99/XRP |

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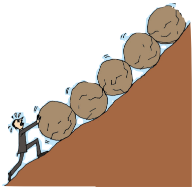

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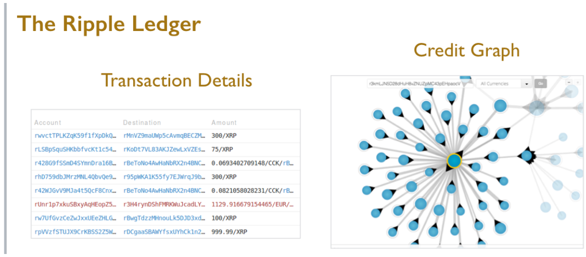

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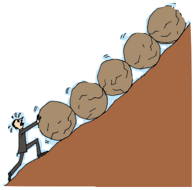
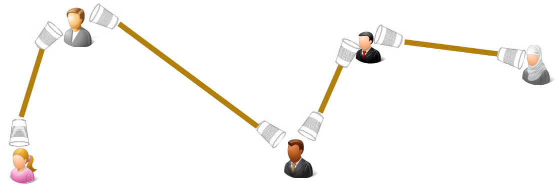


- ✦ SilentWhispers uses distributed landmark routing, secure multi-party computation and 2-step transactions

- ✦ SilentWhispers is feasible in practice and offers interesting alternatives to current emerging payment systems



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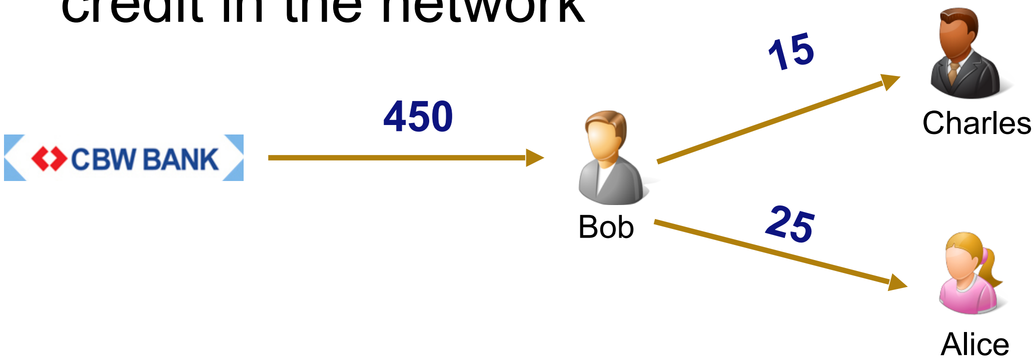

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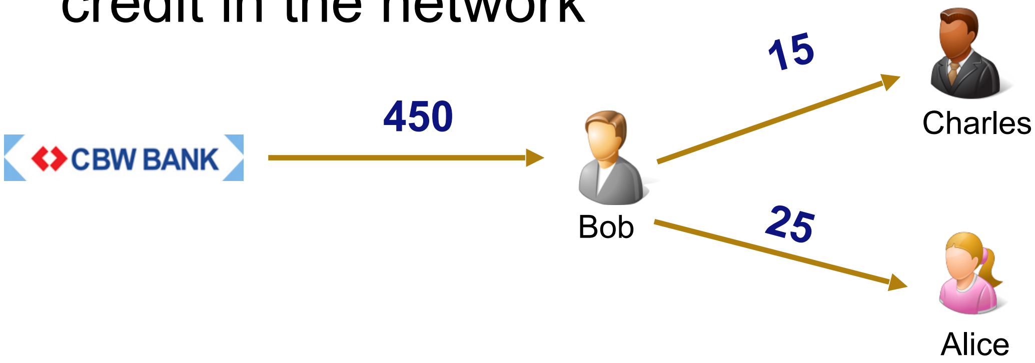

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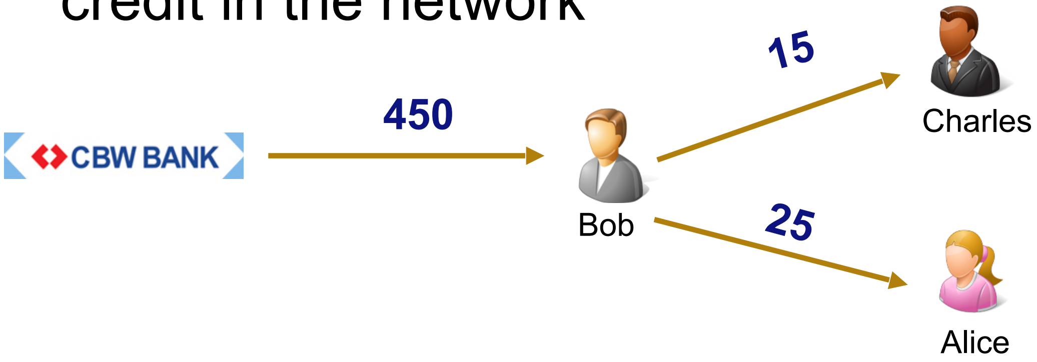

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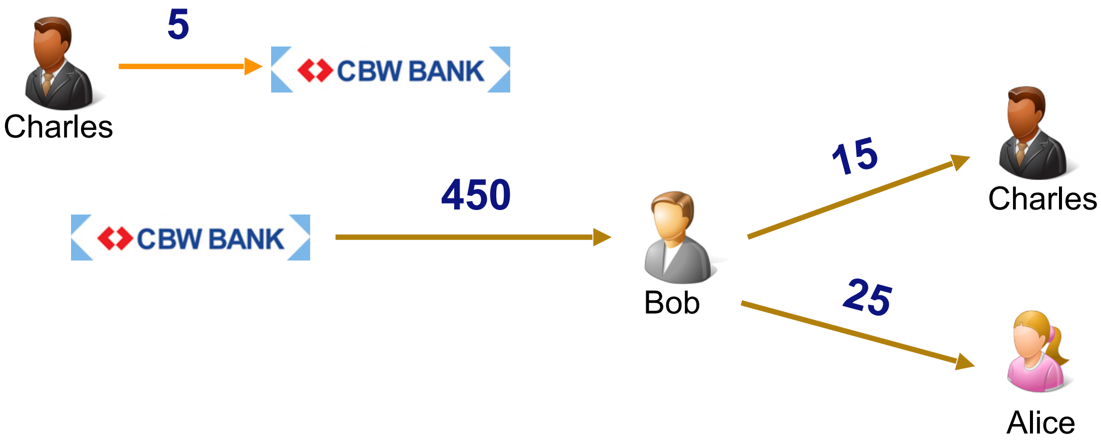

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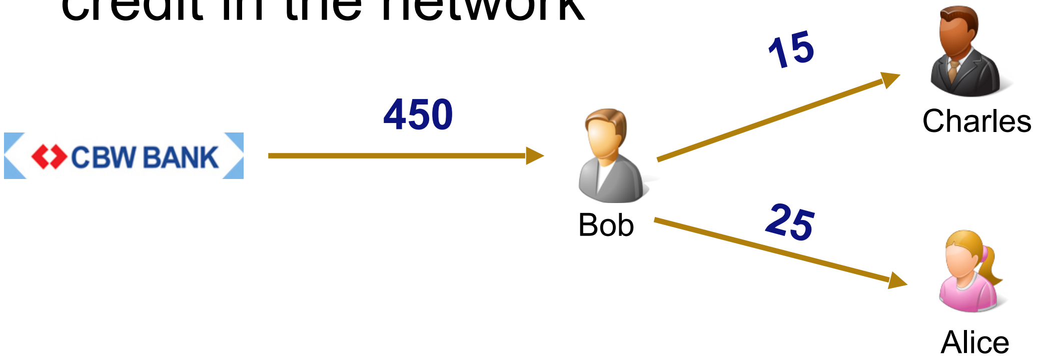

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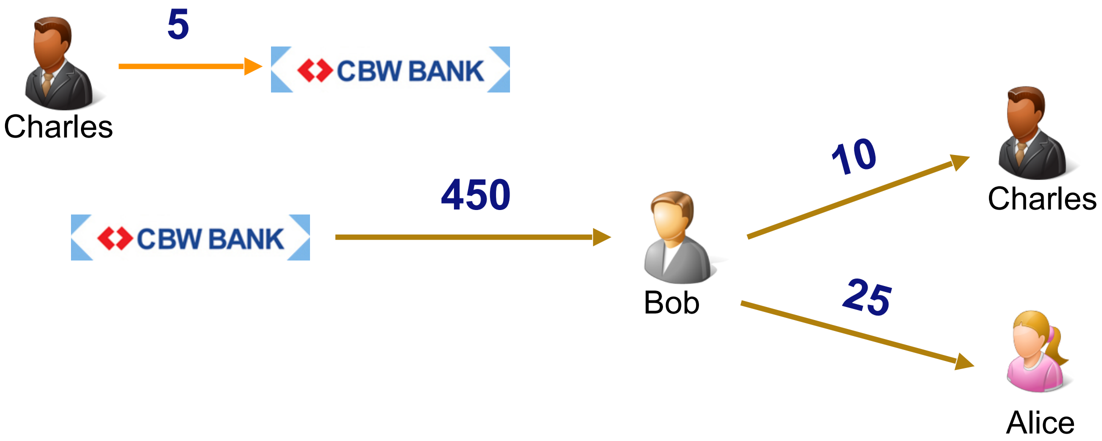

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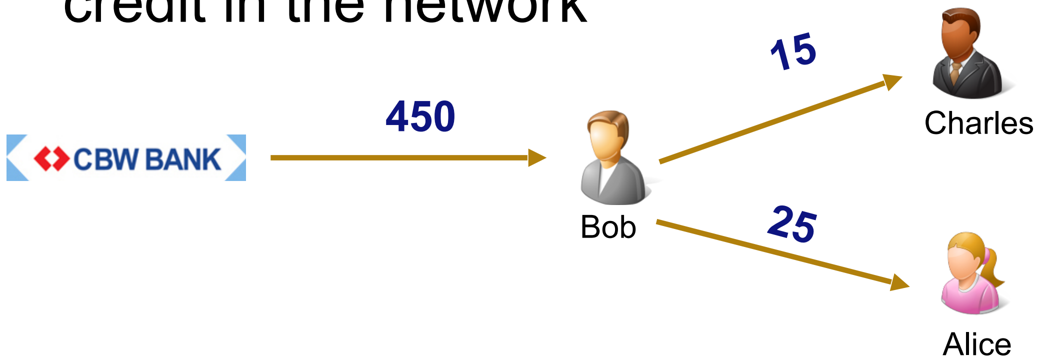

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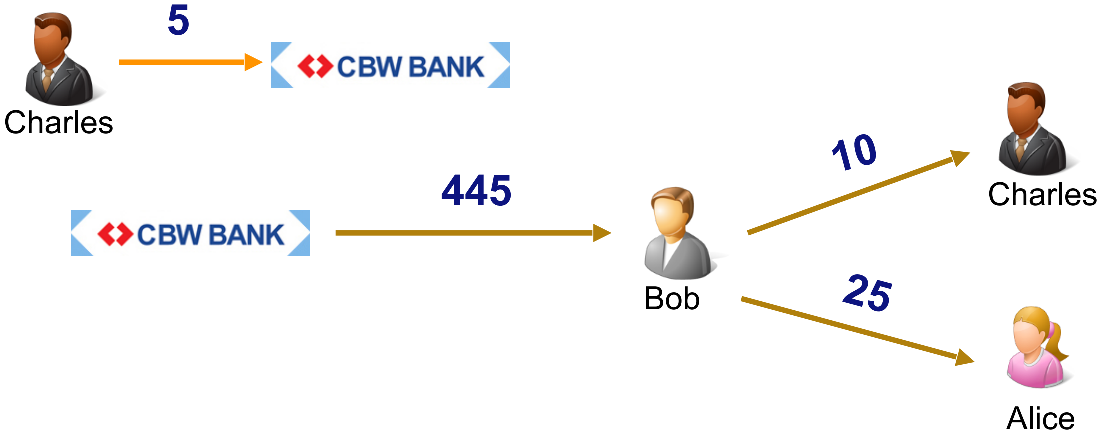

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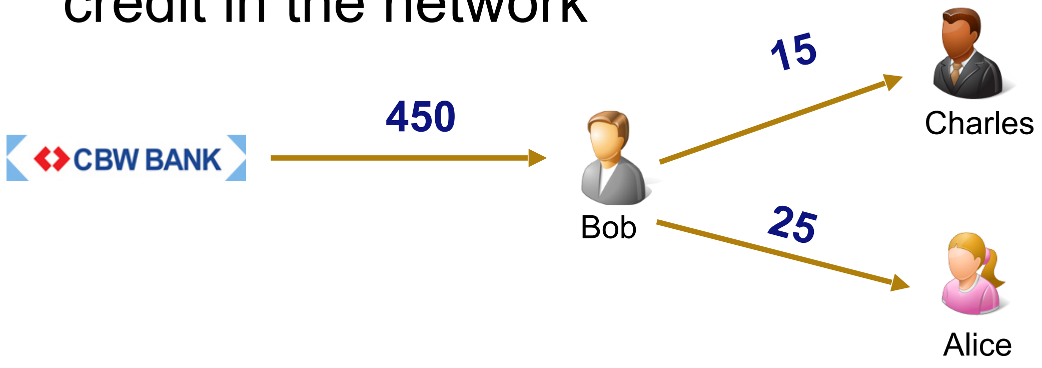

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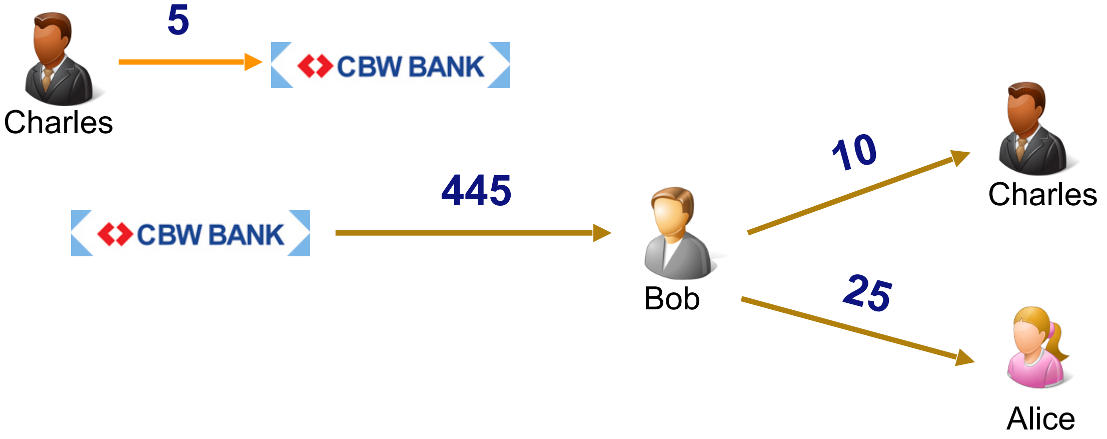

In-flow = ~~450~~ 445
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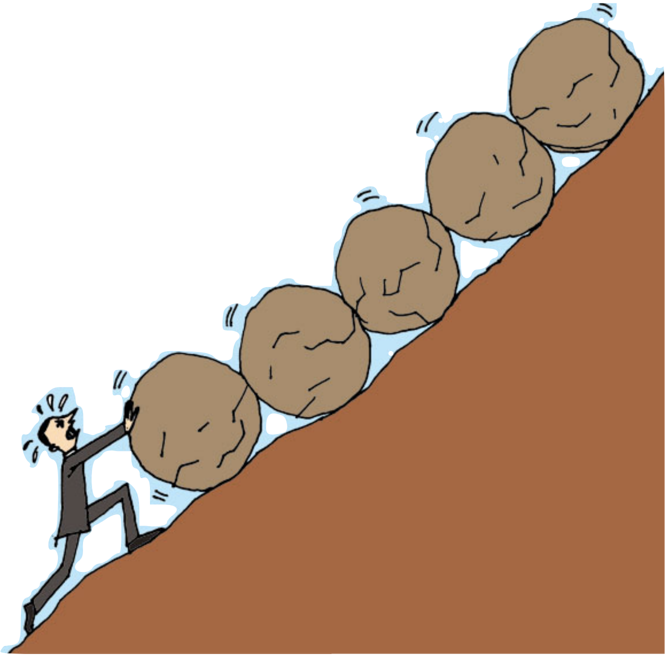
# Challenges

- Find paths between users
- Calculate credit available in the path
- Ensure integrity of transactions
- And more …



# The routing challenge

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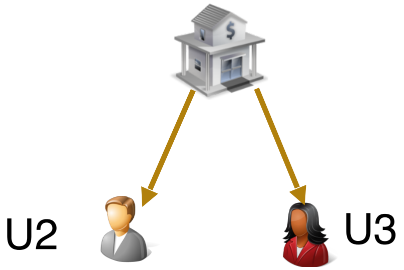

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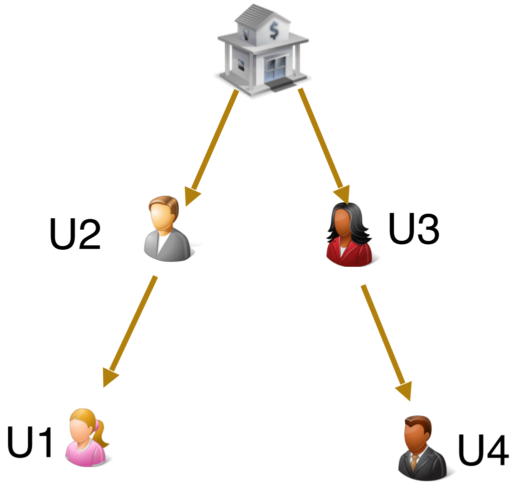

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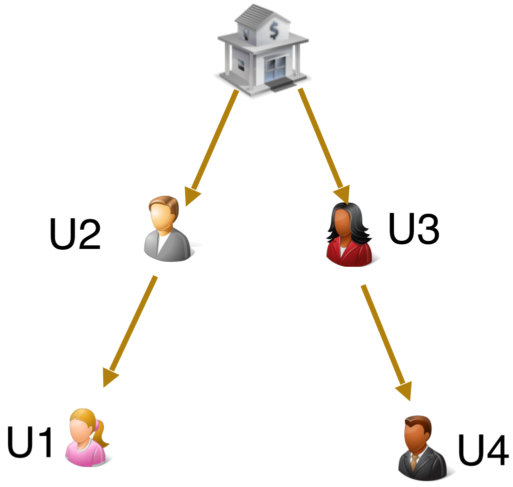

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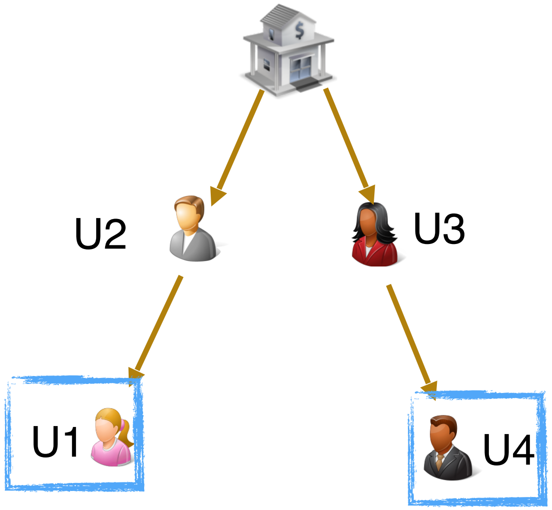

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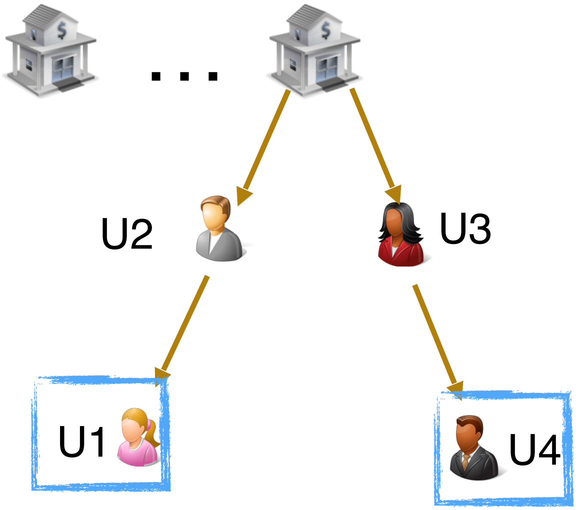

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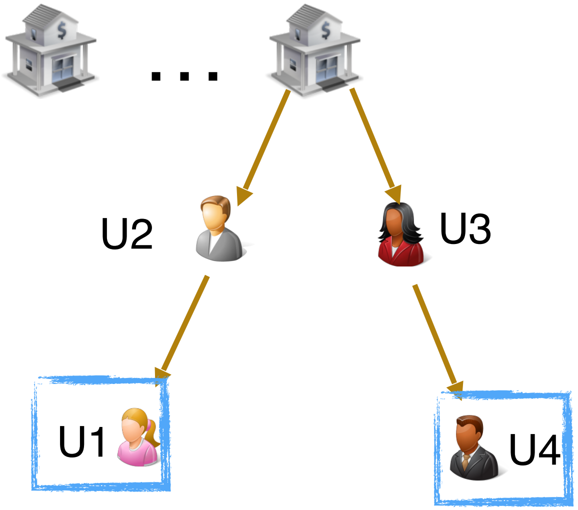
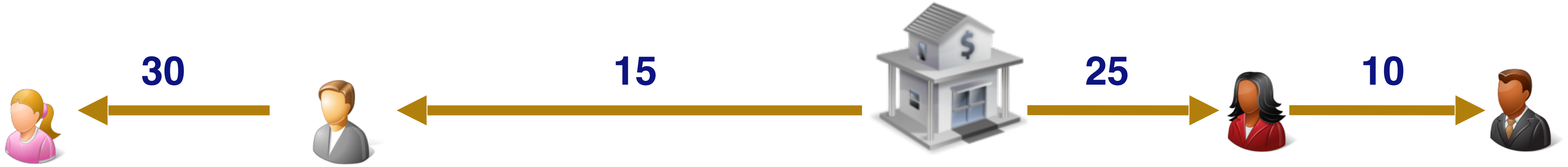
  - Enough in practice[1,2]
  - More efficient than max-flow[1,2]



[1] [Our work in NDSS ’15]
[2] [Viswanath et al. EUROSYS ’12]

# Calculation of credit available in a path

# Credit in a Path: SMPC



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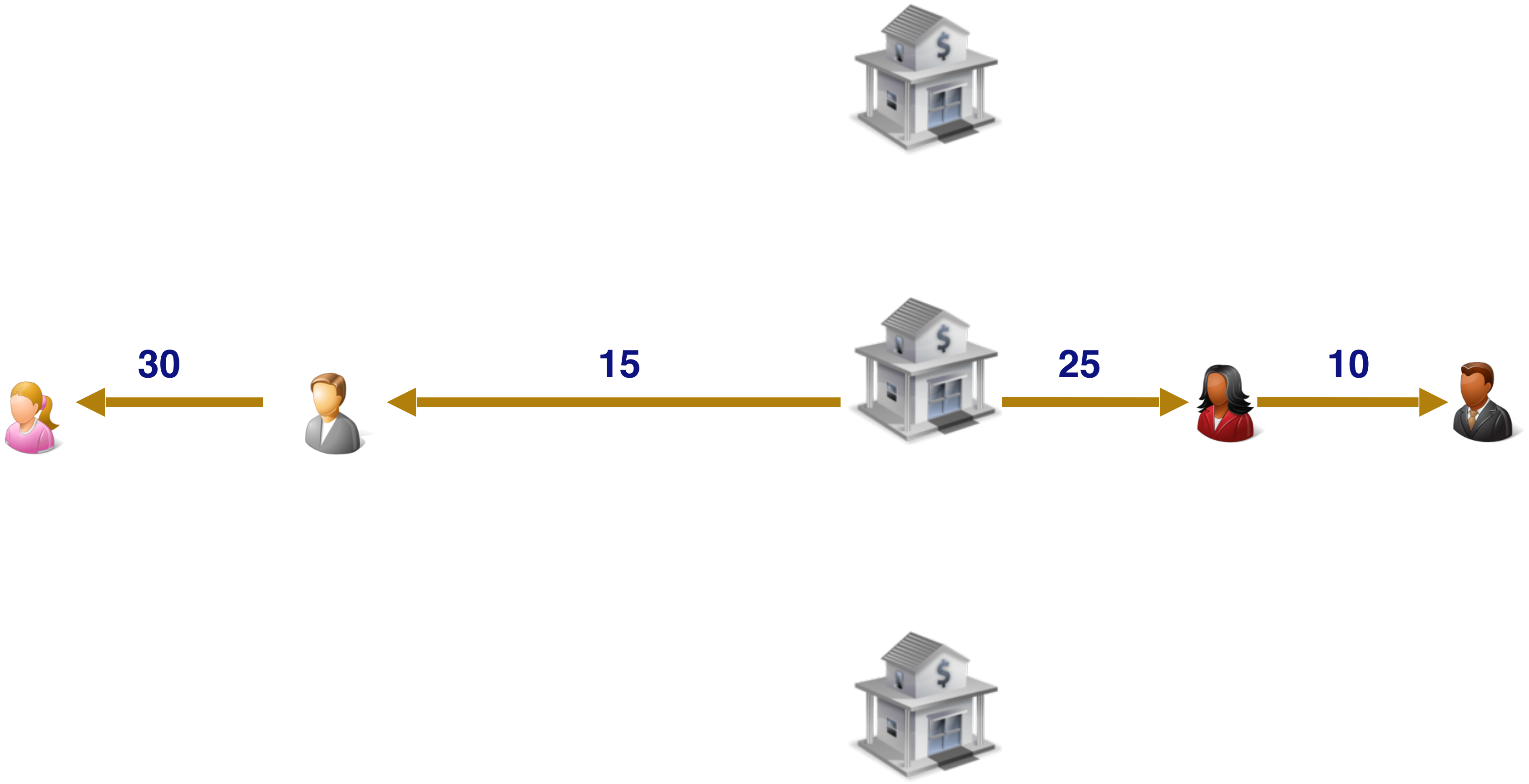

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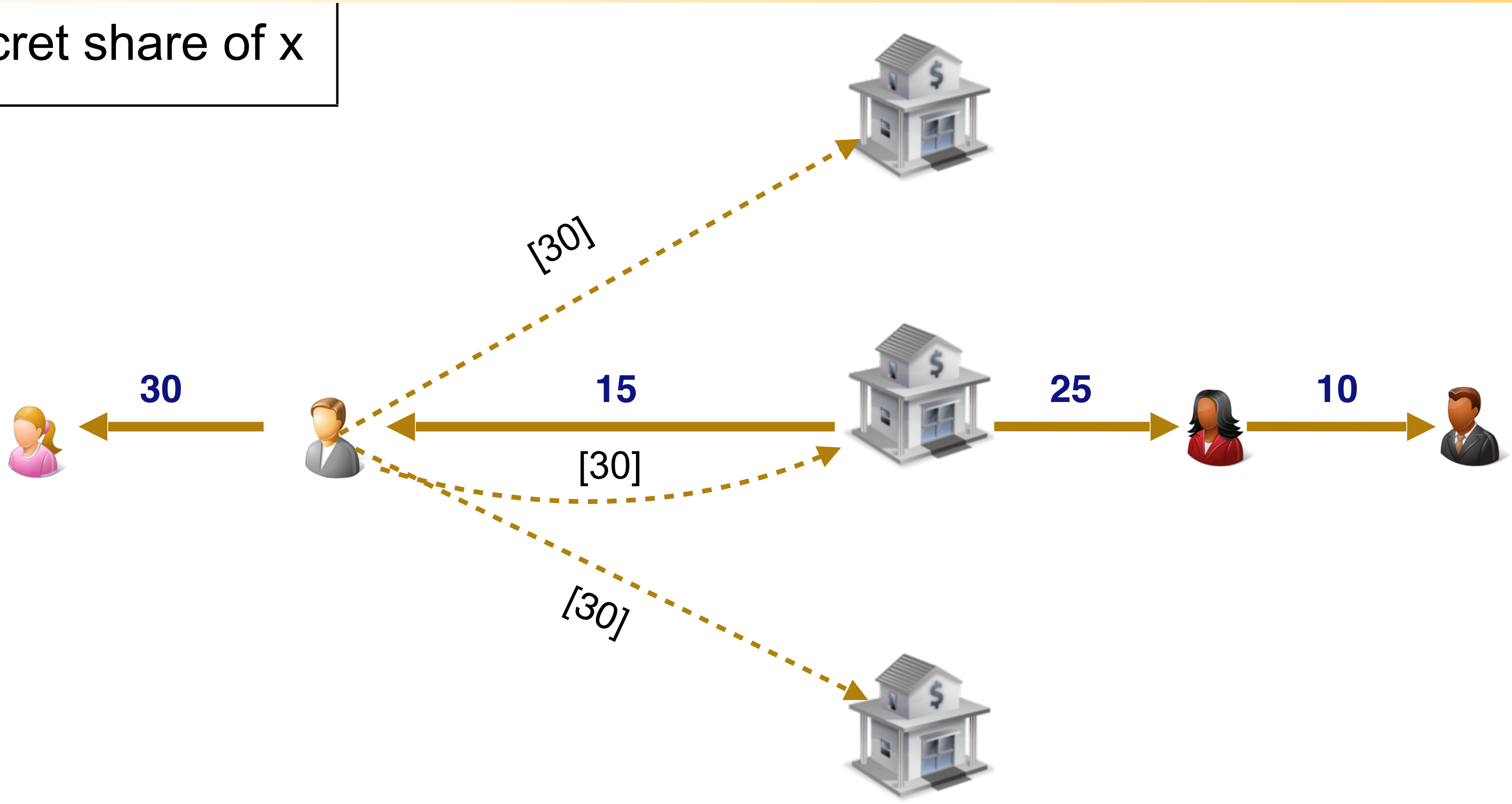

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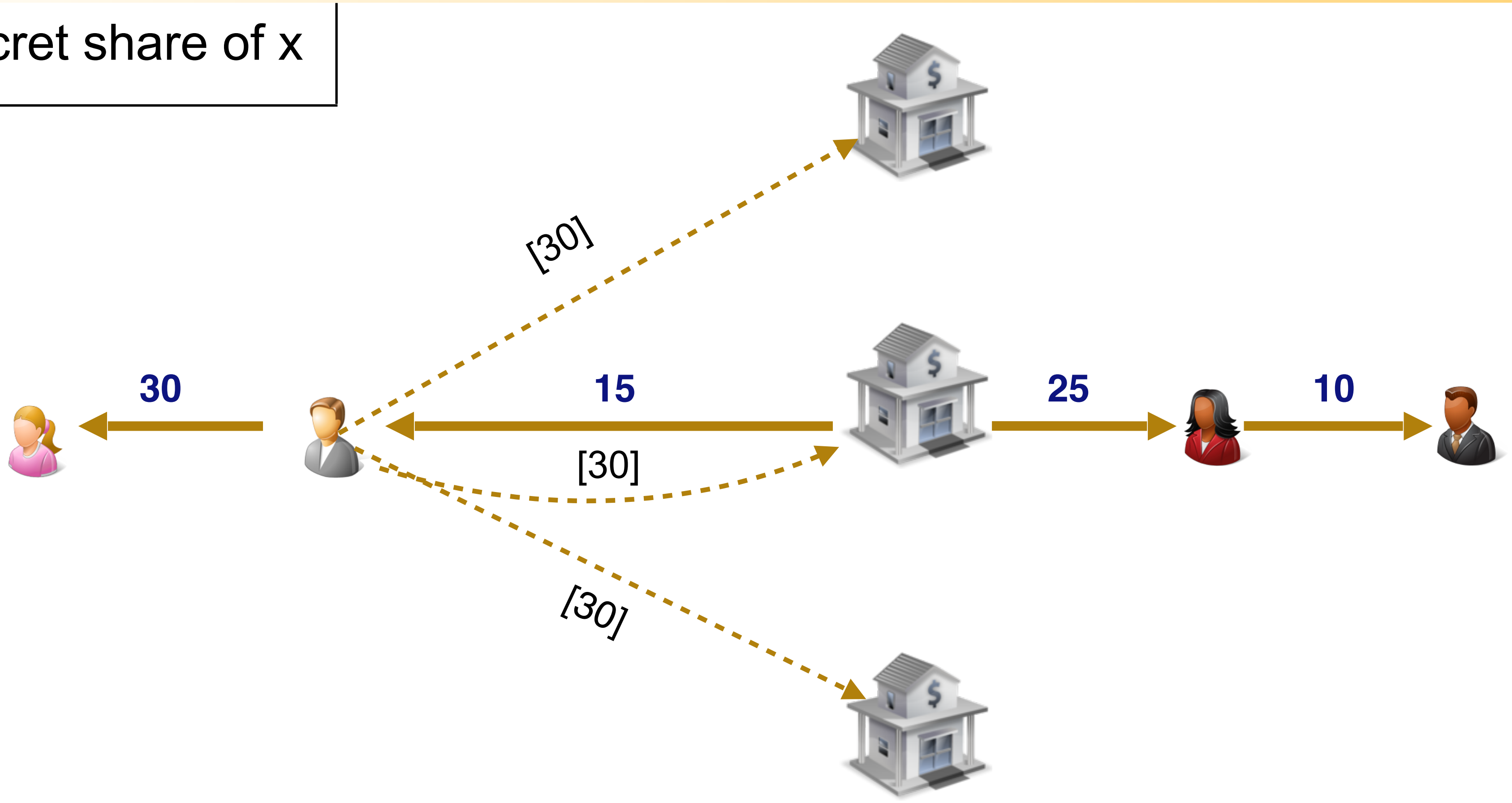

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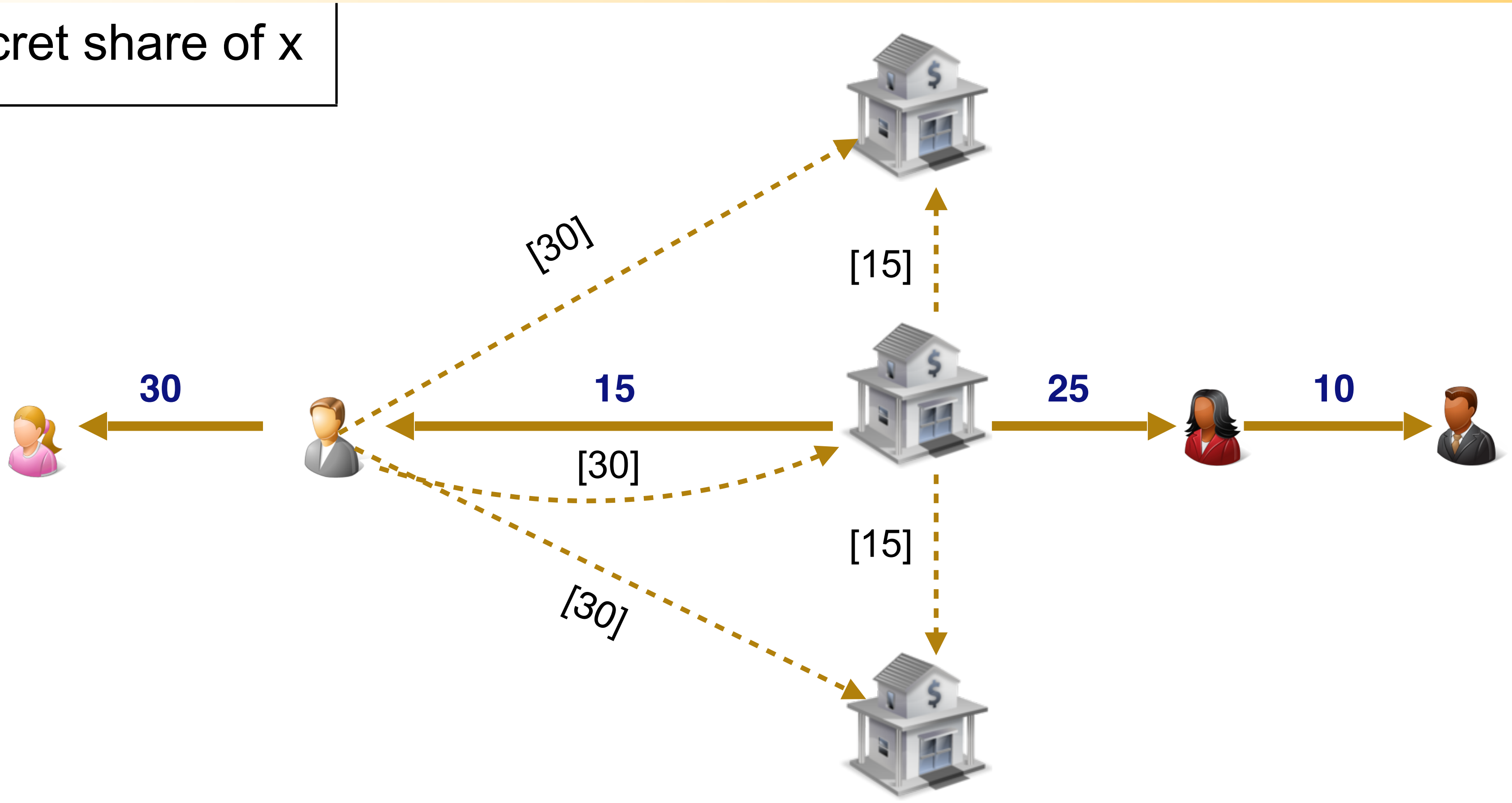

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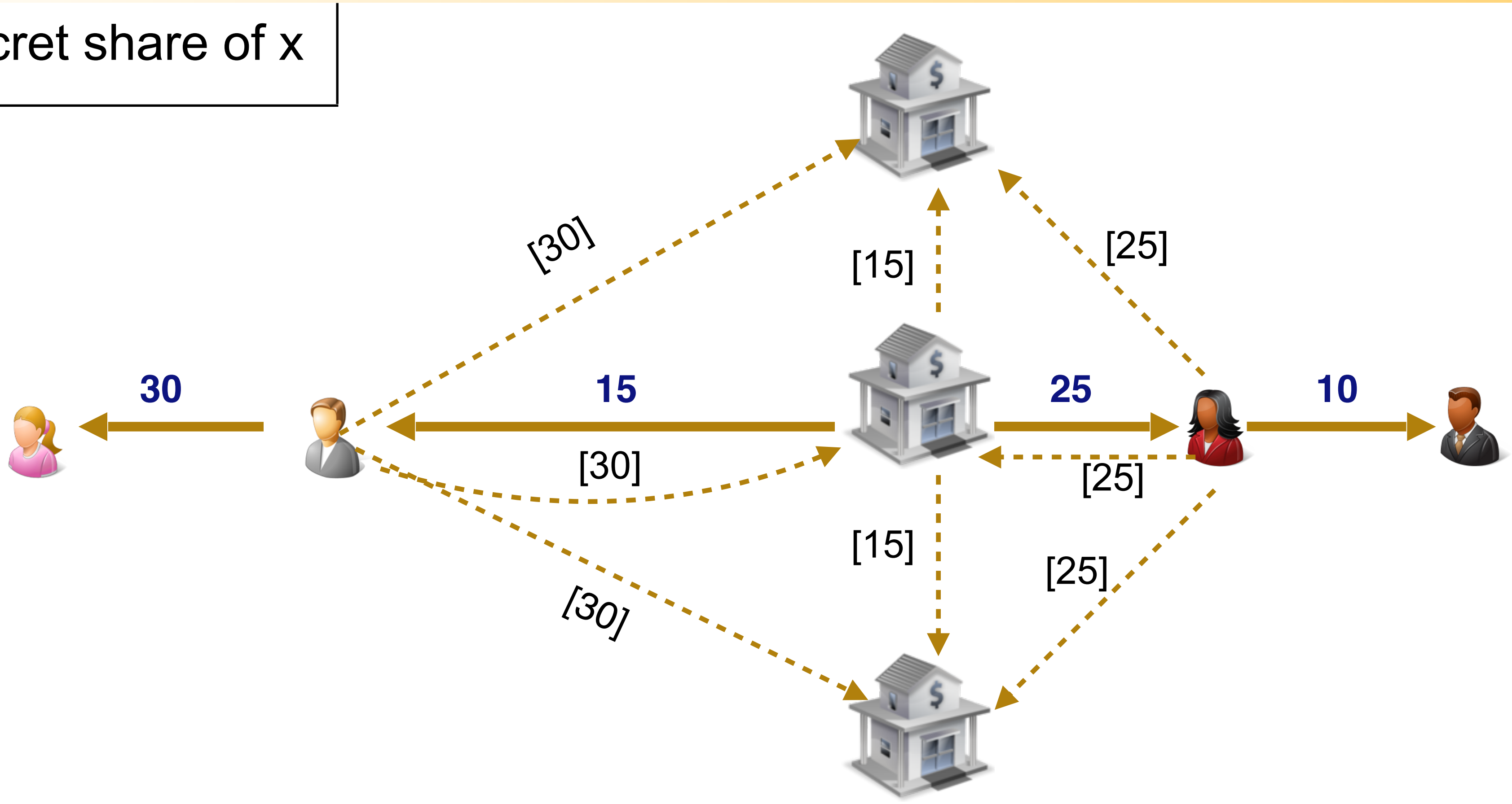

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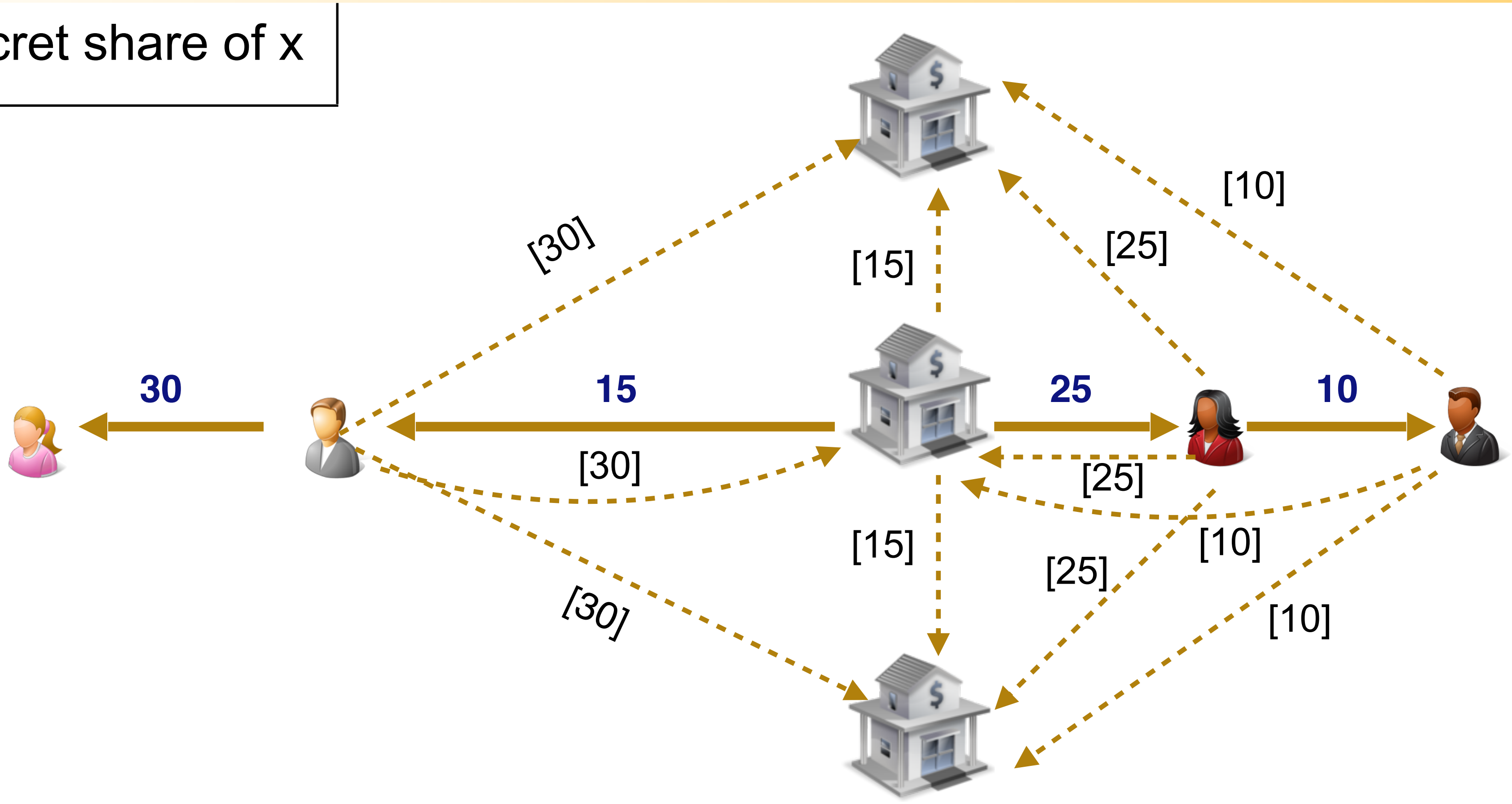

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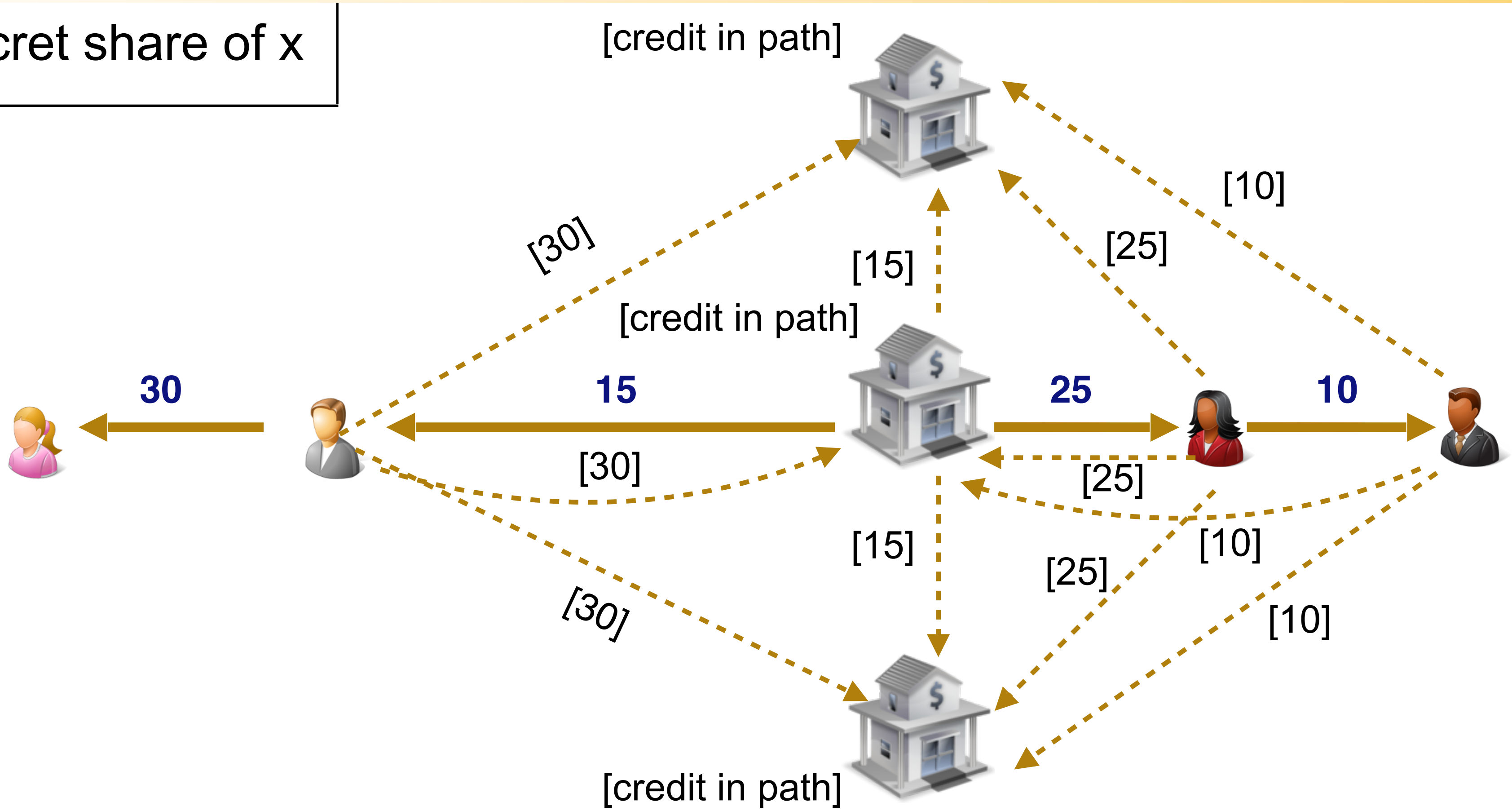

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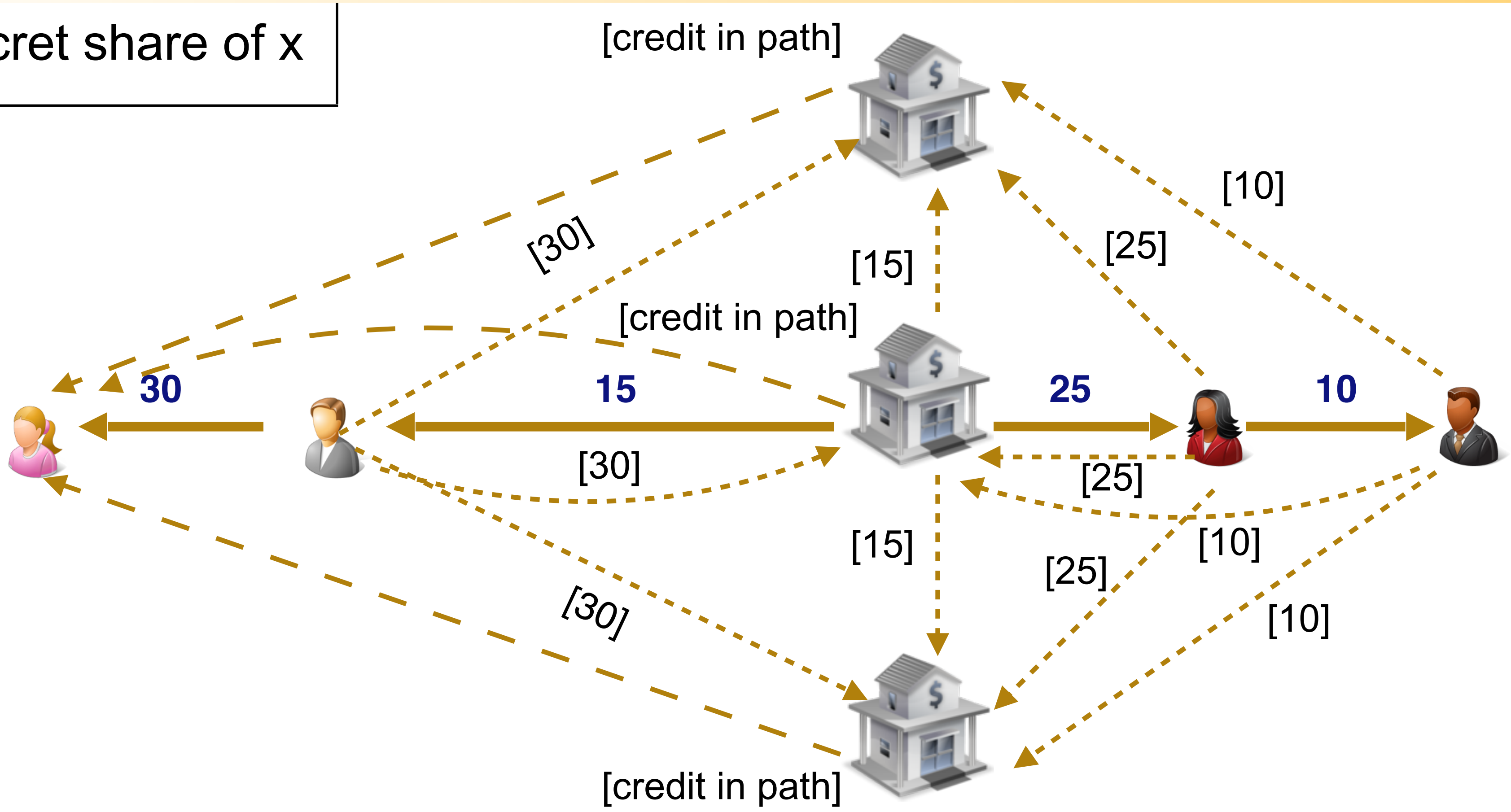

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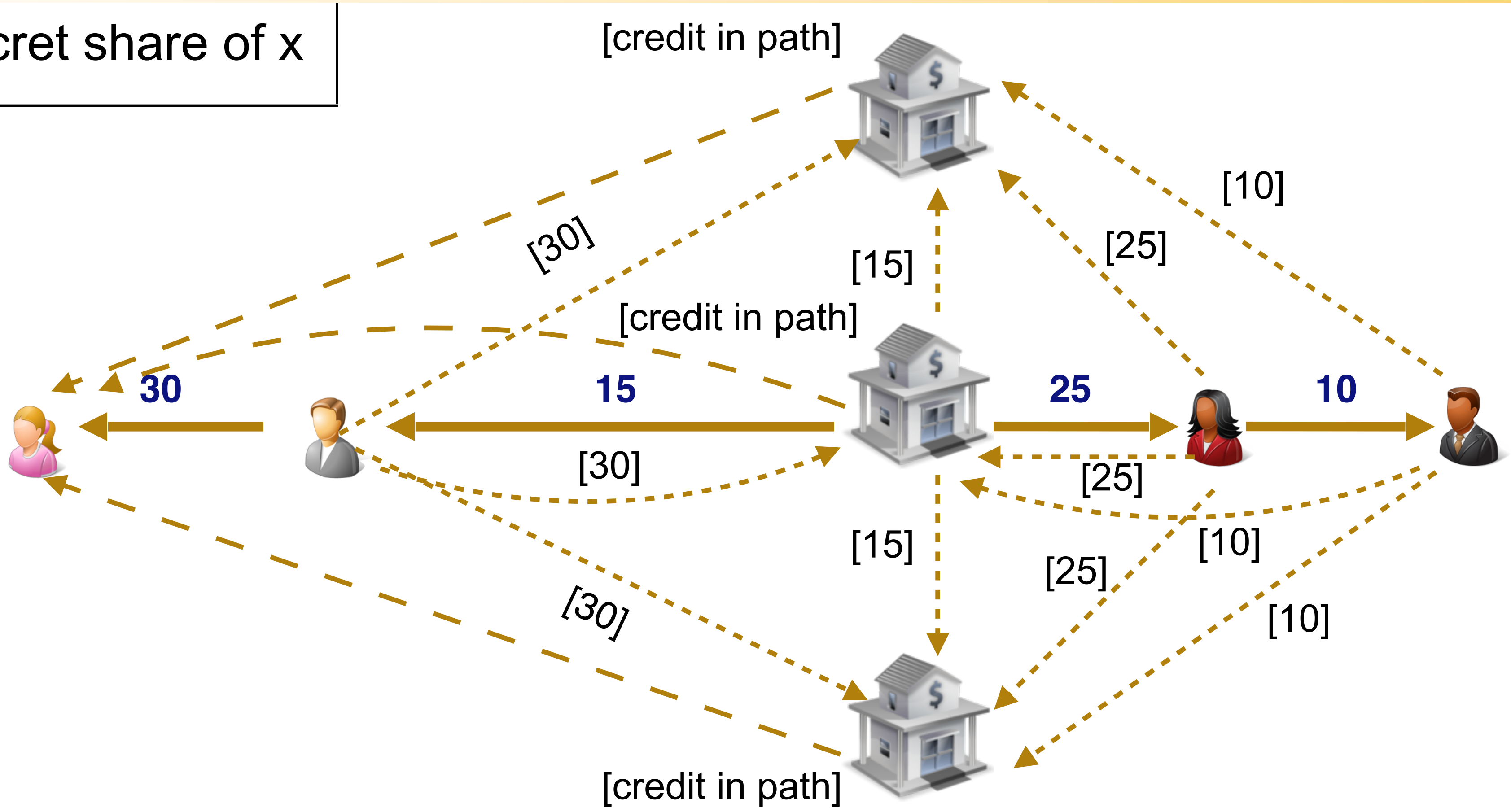

- Given [x] it is not possible to know x
  - Given “enough” copies of [x] one can reconstruct x

# Integrity of the transactions

# Transaction Integrity and Dispute Resolution

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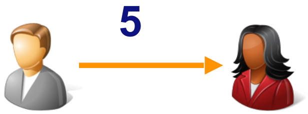
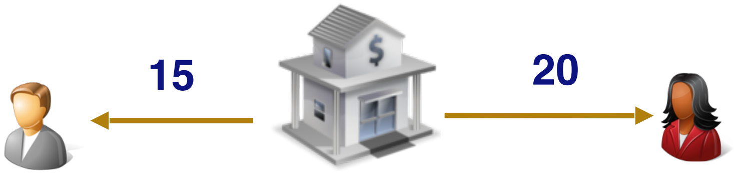
- Example: 



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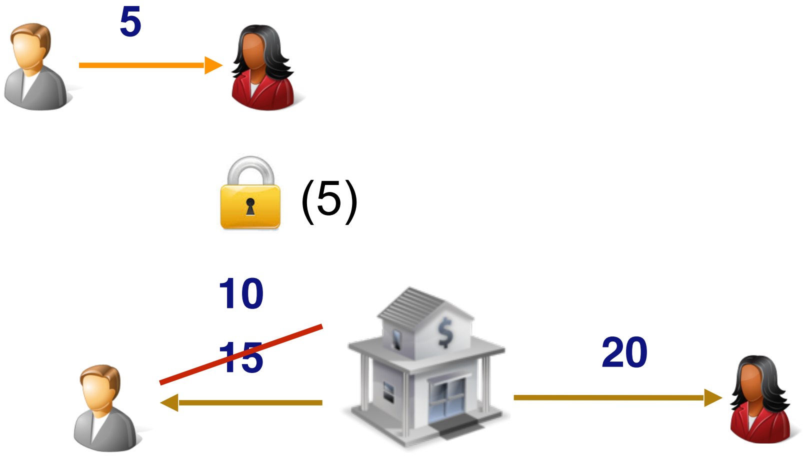

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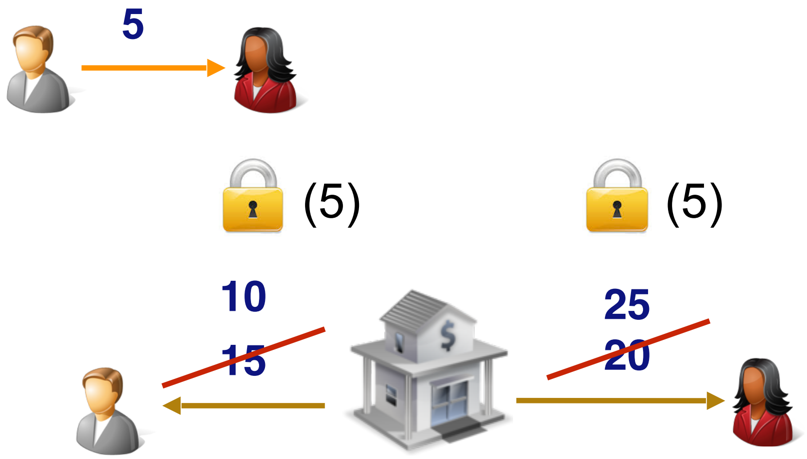

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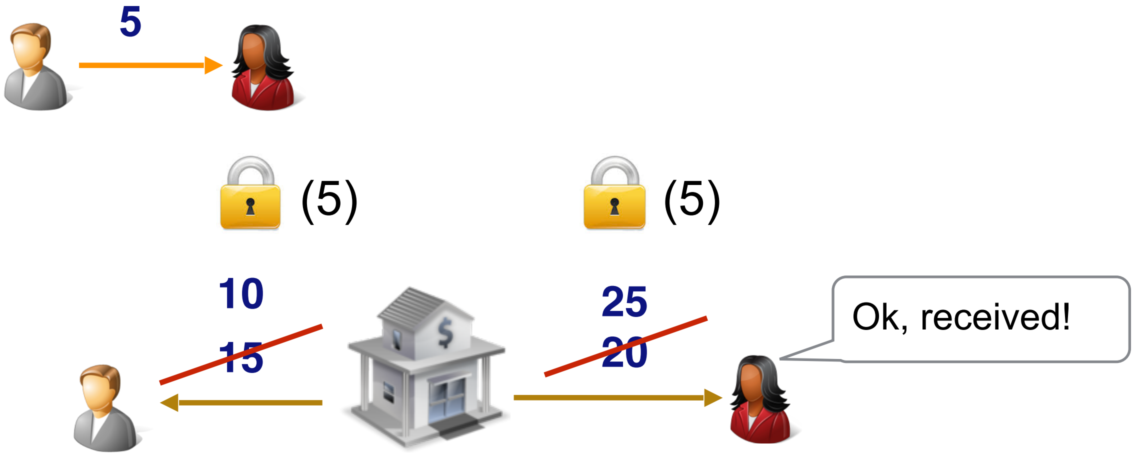

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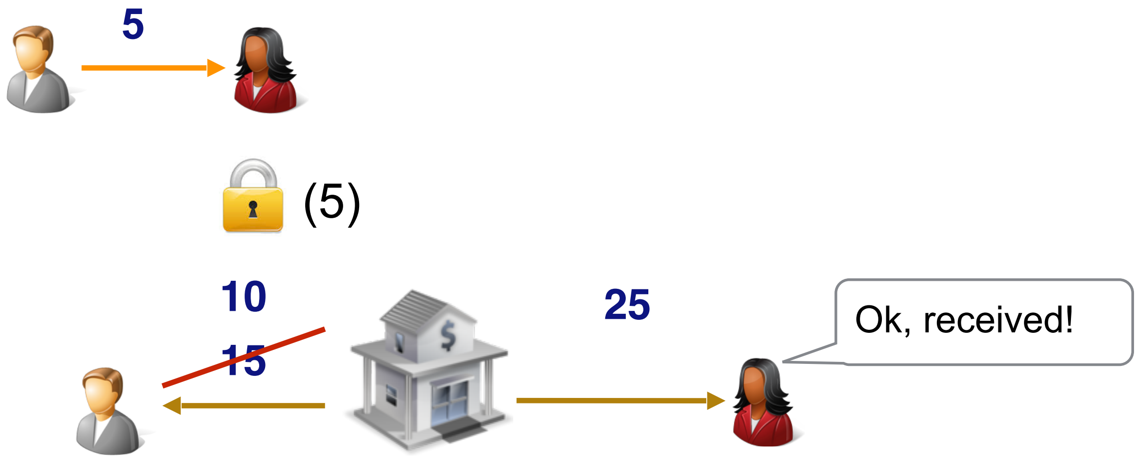

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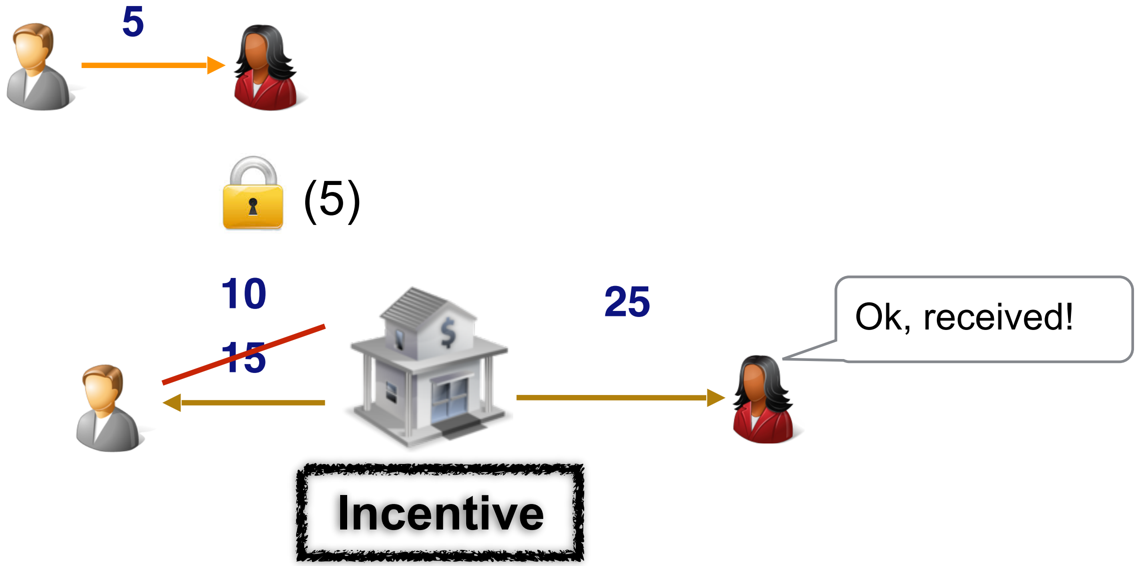

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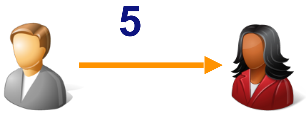

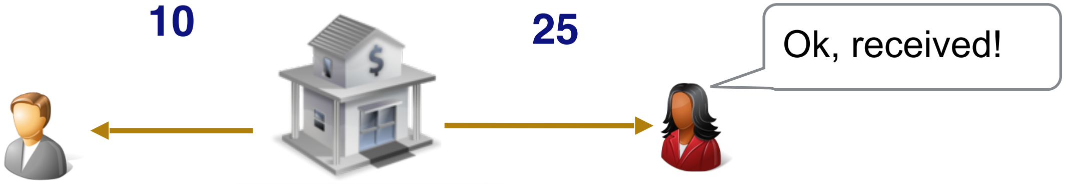

**Incentive**

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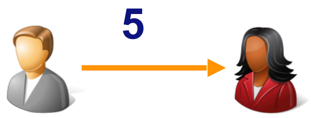

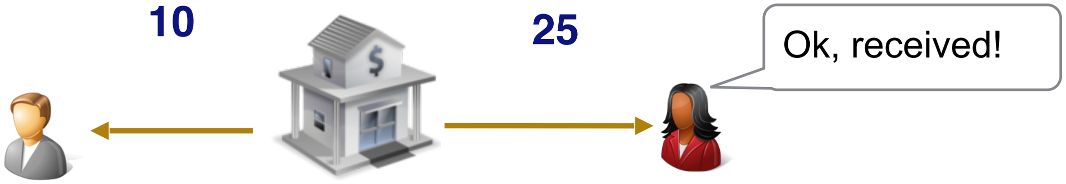

**Incentive**

- Integrity:
  - All landmarks cannot make the user lose credit

# Transaction Integrity and Dispute Resolution

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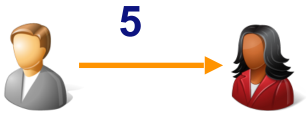
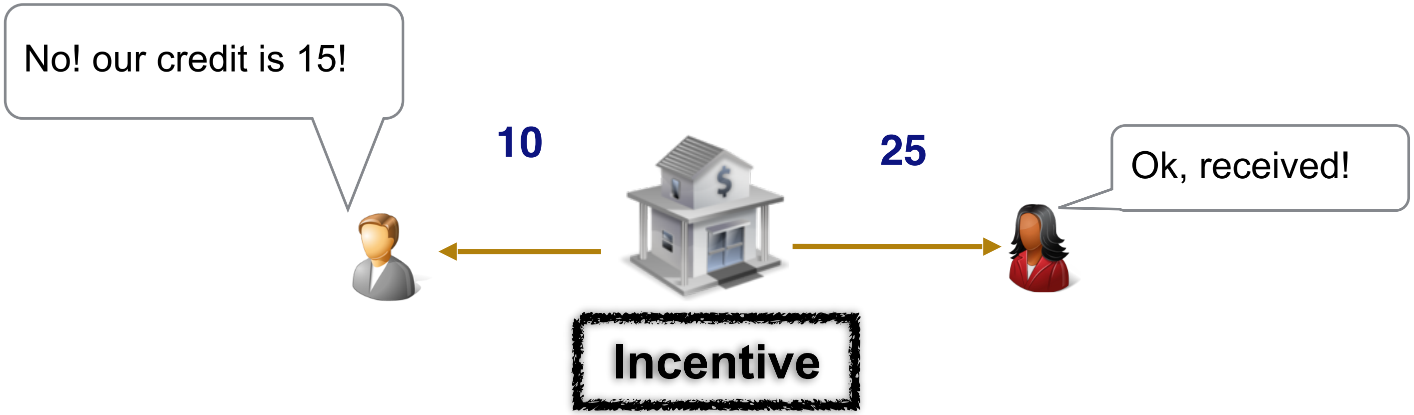
- Example:




No! our credit is 15!

10

25

Ok, received!

Incentive

- Integrity:
  - All landmarks cannot make the user lose credit

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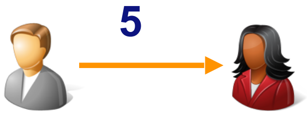

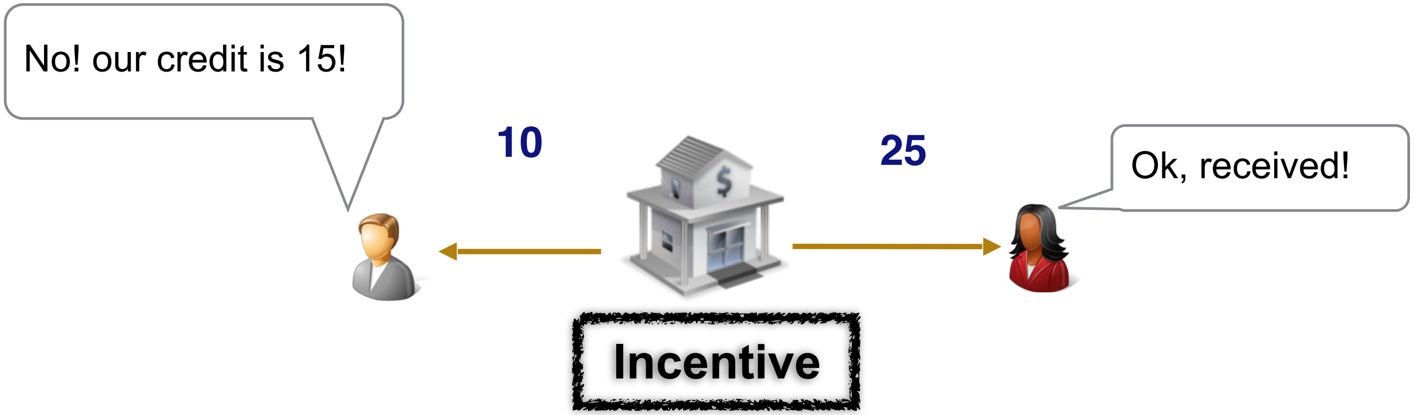

Incentive

- Integrity:
  - All landmarks cannot make the user lose credit
- Accountability:
  - In case of dispute, users must prove the link value
  - Local logs suffice to determine the valid current value
  - The disputed value is bounded

# Evaluation

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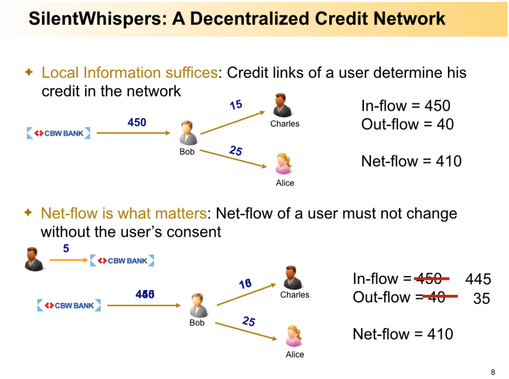

## SilentWhispers: A Decentralized Credit Network

- Local Information suffices: Credit links of a user determine his credit in the network

In-flow = 450
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- Net-flow is what matters: Net-flow of a user must not change without the user's consent

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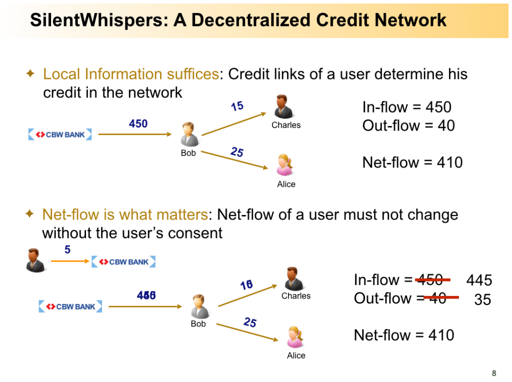

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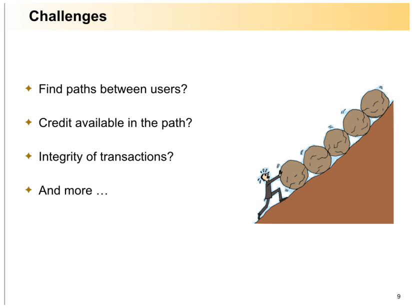

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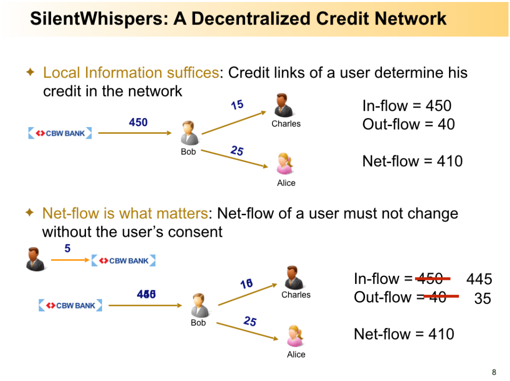

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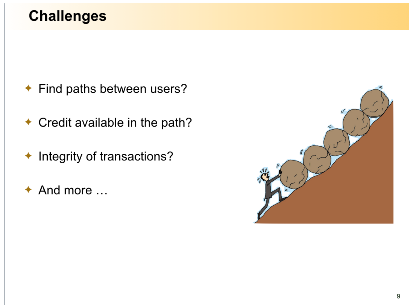

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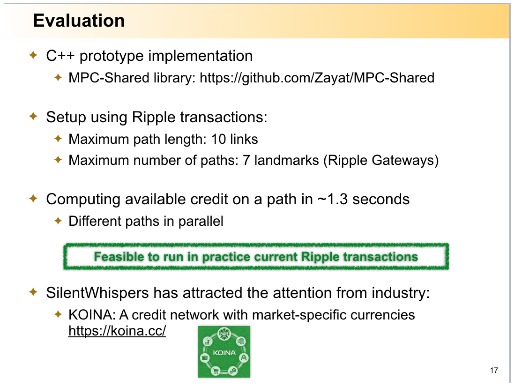

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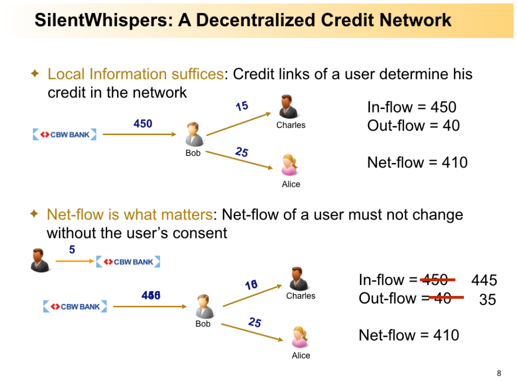

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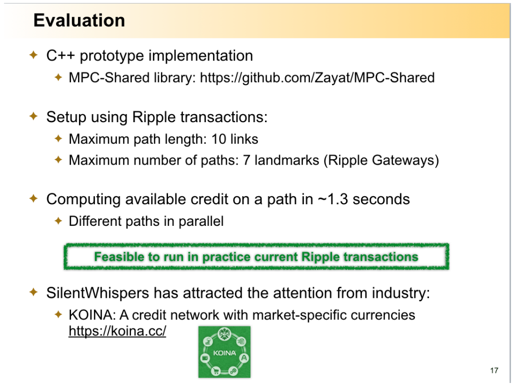

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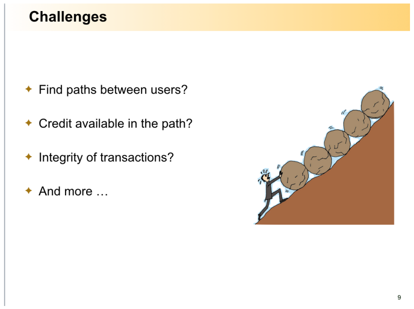

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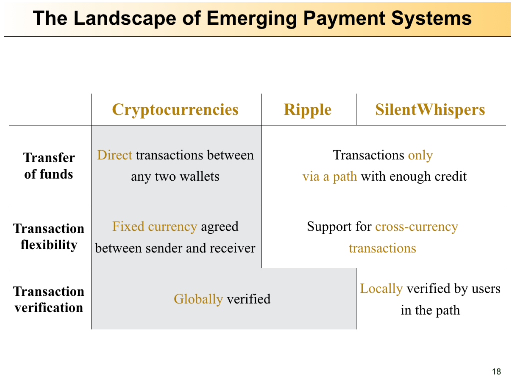

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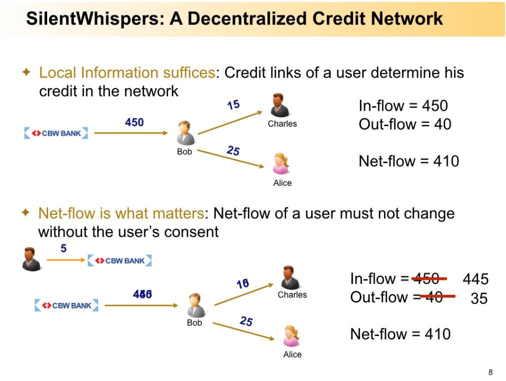

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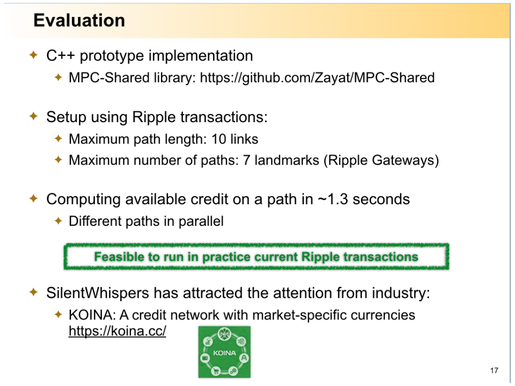

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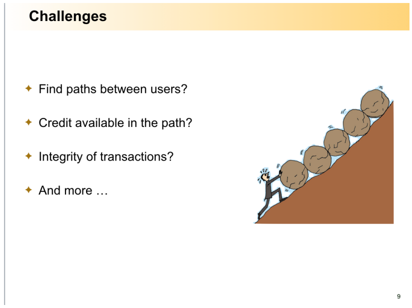

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***@pedrorechez***

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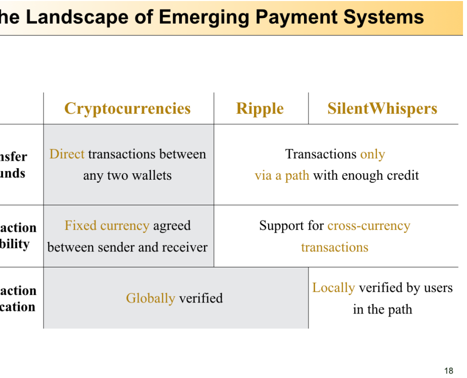

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